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STONE AGE AND PLEISTOCENE
CHRONOLOGY IN GUJARAT



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STONE AGE AND PLEISTOCENE
CHRONOLOGY IN GUJARAT

By

F. E. ZEUNER

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STONE AGE AND PLEISTOCENE CHRONOLOGY IN GUJARAT

BY
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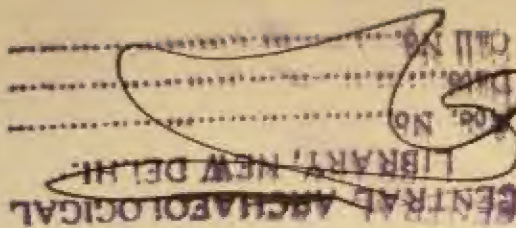
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The First Preliminary Report of the
Sir Dorabji Tata Prehistoric Expedition to Gujarat

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FOREWORD.

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Since 1941 the Institute has been conducting prehistoric explorations in Gujarat, first at the instance of the late Rao Bahadur K. N. DIXSHIT, who as the then Director General of Archaeology in India initiated the work, and later with a financial grant from the University of Bombay. When it appeared that the field was very extensive and promising, and larger funds and more intensive explorations were necessary, the Institute issued an appeal for funds in 1945. This was very sympathetically received by the authorities of the Sir Dorabji Tata Trust and they sanctioned the Institute's request in full. Thus the Sir Dorabji Tata Prehistoric Expedition to Gujarat was organized in 1946-47. When it returned from the field, certain problems had still remained unsolved, particularly the dating of the prehistoric cultures. Dr. R. E. M. WHEELER, the then Director General of Archaeology in India suggested that Dr. F. E. ZEUNER be invited to make an environmental study of Gujarat prehistoric cultures with a view to dating them. This was also made possible by the ready response from the Dorabji Tata Trust and the N. M. Wadia Trust.

Free

Excepting the studies carried out by Drs. DE TERRA and PETERSON on behalf of the Yale and Cambridge Universities, these studies are the first of their kind to be sponsored in India, and we owe them primarily to the enlightened Houses of the Tatas and Wadias, and to their active financial help. The Institute is indeed grateful to both of them. We are also thankful to Dr. R. E. M. WHEELER for obtaining the Government of India's cooperation and to Dr. F. E. ZEUNER for accepting our invitation.

6th September 1950.

S. M. KATRE.

Publisher

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I. INTRODUCTION.

In January and February, 1949, an expedition was sent jointly by the Archaeological Survey of the Government of India and the Deccan College Post-Graduate Research Institute, Poona, to Gujarat and the adjacent parts of the Deccan. The latter was helped by the Wadia and Tata Trusts. Its purpose was (apart from the training of Indian prehistorians) to study the implement-bearing strata, which had been found mainly in the valleys of the rivers, to establish their typological affinities and their geological context, and if possible to arrive at a chronology of this earliest evidence of the presence of man in this part of India. The present paper contains a summary of the field observations and of the interpretation which may be given to them after the macroscopical study of the samples collected. A very large number of samples were taken during the expedition, and their physical and chemical investigation will require considerable time in the laboratory. Since the basis for the study of the properties of deposits is their mode of occurrence in nature, it is proper to put these field observations on record without delay.

The area has been studied by a comparatively small number of workers. The first was BRUCE FOOTE who, in 1898, published his excellent *Geology of Baroda State*. Work on the prehistory of Gujarat was again taken up and its results published in an important memoir by Dr. H. D. SANKALIA (1946). Further notes on the geology of Gujarat which have a bearing on the subject are to be found in Dr. SANKALIA'S *Archaeology of Gujarat* (1941) and Mr. GADRE'S *Archaeology in Baroda* (1947). There are also a number of special papers which will be referred to individually. Valuable information on the modern environment, which provides the basis for any reconstruction of the environment of early man are to be found in C. D.

1 First report on the Indian Geochronological Expedition, 1949,

DESHPANDE's *Regional Geography of Western India* (1948). Whilst working in the field I enjoyed the efficient co-operation of my friend Dr. H. D. SANKALIA of the Deccan College Research Institute and of a team of archaeologists, among whom I wish to mention especially Messrs. M. N. DESHPANDE and K. V. SOUNDARARAJAN of the Archaeological Survey of India, Dr. B. SUBBARAO and Dr. IRAWATI KARVE of the Deccan College Research Institute. Mr. VATSRAJ of the Union Engineering Corporation, Ahmedabad, Mr. PATEL, Baroda and Mr. A. S. GADRE of the Baroda Archaeological Department kindly helped us in many ways. I wish to express my sincere thanks to all these friends for their efficient help and in so doing I include those many others who for want of space cannot here be enumerated by name.

This paper is divided geographically, according to the river systems studied. The most important part is that on the Sabarmati system which has provided the most complete sequence and which, therefore, has been adopted as the standard for the discussion of the others. The arrangement is from north to south, which is not merely convenient geographically but demonstrates clearly the gradual climatic change with the geographical latitude. Present-day topographical descriptions are almost completely omitted, since these and their bearing on archaeology have been dealt with adequately by SANKALIA (1946) and DESHPANDE (1948). The description of localities has been arranged in such a way that the sequence of geological events and the relative dating of prehistoric industries are reconstructed going from the present back into the past. The reason for doing so is that this is the normal method of work applied in stratigraphical geology. It tells us which of the deposits are older than others, so that in the end we arrive at a minimum age for each of them. It will be seen that this is significant as regards the age of the artifact-bearing gravels of the Sabarmati system. Moreover, going back from present-day conditions gives us a solid foothold in the period with the conditions of which we are naturally most familiar.

II. THE SABARMATI RIVER.

Modern Soils (Z).

The modern soils which have developed on the almost level plateaus of Northern Gujarat are strongly influenced by wind action. A large amount of fine sand and silt is blown about as a result of intensive agriculture which destroys the vegetation cover and exposes soil particles to air currents. It is one of the worst effects of the usual agricultural practices, that an enormous amount of valuable surface soil is thus carried away and often redeposited in inconvenient places. Chemical weathering which, under normal conditions, *i.e.* with a permanent cover of vegetation, would form a deep layer of alteration in which plants find an adequate food supply, is much impeded by the effects of wind action. Where the surface is losing material owing to "deflation", the soil-forming processes have to penetrate deeper and deeper into the fresh substratum which means that these soils are not able to mature. On the other hand where the wind is accumulating sand and dust, the surface layer is added to constantly and the soil-forming processes have to weather this additional material as well as the subsoil occurring *in situ*. Again maturation of the soil is impeded. In both cases fertility suffers. It is the curse of agriculture, especially in climates with a dry season, that it destroys the layer of soil on which it depends. Vast regions, like parts of Mesopotamia, the border lands of the Sahara and so forth, lands which carried great ancient civilisations have been turned into desert. It will be necessary for modern man to control this process by all possible means.

In the present context this observation implies that few mature, and therefore typical, soil profiles are to be found in Northern Gujarat which would enable us to get a clear idea of the types of soils which are being formed under present-day climatic conditions. The soil sections which I was able to see appear in the plains to be related to black-earths, and chestnut soils. In some places, especially on slopes near Dharoi, Taranga and Hadol, the soils tend to be orange or red in colour, and it is suggested that if the country were carrying

its natural vegetation of light forest, allitic red-earths would develop. Where the calcareous sand is thin and where impermeable rocks are forming flat surfaces, black cotton soil (regur) is observed. In the vicinity of Bapsar Lake (near Dharoi), where crystalline rocks form hills rising from the wide, flat-bottomed valley floors, a catena is frequently to be seen, starting with black soils on the flat ground and passing through yellow soils into red soils on the slopes. Not all black soils, however, are of the heavy regur type; some are more reminiscent of chernozom as found in the continental steppes of South Russia and elsewhere.

At Kamalpur, near Valasna, a flat expanse of cotton soil with no drainage, is used for rice-growing in the monsoon season. This ground was covered with forest until about 25 years ago. I was not able to ascertain what type of forest this was, but this locality suggests that cotton soil might occasionally form under a cover of woody vegetation. This, however, is unlikely to be the rule.

As an example of a soil from the sand-covered plains of Northern Gujarat with good drainage, the surface soil of Langhnaj may be mentioned. It is calcareous throughout and greyish-brown. The humus content decreases very gradually downwards and the kunkar (calcium carbonate) concretions start at about 5 ft. below the surface; they are small and numerous. This soil profile is almost certainly immature.

Another section exposed by the digging of a large well was seen on the way from Vijapur to Hirpura, about a mile south of the village. It showed, on level ground and on the usual sandy-silty subsoil, a blackish-brown non-calcareous soil which might be regarded as transitional from a black-earth to a chestnut soil. It was about 6 ft. thick and its reaction (within 3 ft. of the surface) was $\text{pH}=7.2$. It had retained a sandy texture and contained a large amount of alkali-soluble organic matter.

From these and other observations it may be inferred that red loamy soils and true laterites are not formed in this area at the present time.

Latest Dry Phase (Y).

The section exhibited by the excavations at Langhnaj, on

Andhario Hill (SANKALIA, 1946, p. 79) are composed of the following sequence:

- (Z) Modern greyish-brown, calcareous soil developing on (Y).
- (Y) Brown, calcareous sand passing into (Z) and affected by surface weathering. In the lower part of this bed microliths were found associated with pottery as described by SANKALIA (Neolithic or Iron Age). The thickness of this layer is here about 4 ft., but varies with the section.
- (X) An horizon faintly stained by humus, evidently an immature buried soil with a somewhat undulating surface. Thickness difficult to assess as it passes imperceptibly into (W). This land surface coincides with an archaeological level which has produced human skeletons, animal bones and microliths, also sandstone slabs flattened on one side and used for grinding, but no pottery.
- (W) Light yellowish-brown sand, calcareous and containing small kunkar nodules from 5 ft. down.

This section (fig. 2) is situated on the top of a small hill, which is gently inclined on the south-west side and steep on the north-east side. It is not U-shaped though many similar hills in the neighbourhood are so. These U-shaped hills are open towards the south-west. They are superimposed on an almost level plain and since stones and pebbles are absent from the sand which they contain and since this sand is of an exceedingly even grain-size, they are likely to be ancient dunes. The material constituting them, however, is too coarse to be called a loess (as done by Foote and others) and should be classified as a fine sand. Furthermore there are depressions, temporary water-pans, to the south-west of many of these hills. They appear to be "blow-outs" from which the material which now constitutes the dunes was removed by the wind. Andhario Hill shows by its cross section that the wind that shaped it came from the south-west, the prevalent direction of the wind even at the present-day. The tail-like extensions of the U-shaped hills point in the same direction. This may be regarded as evidence that, when the wind was forming these dunes, there was sufficient vegetation present to fix part of the dune-sand on the flanks of their moving bodies (fig. 3).

These dunes, however, are not recent. The section shows this clearly. The dunes were already in existence at the time of the microlithic, pre-pottery occupation at Langhnaj and were at that time fixed by vegetation forming the buried soil horizon (X). From this it must be inferred that the sand (Y) between the buried soil and the modern soil indicates merely a revival of wind activity in Neolithic to Iron Age times which was followed by a last phase of fixing by vegetation (formation of the most recent soil). It indicates, therefore, a slightly drier phase, or at least an intensification of wind activity. Since we know from archaeological evidence that at that time an agricultural population was present in the area, it is conceivable that the increase of wind activity was due to their appearance on the spot. On the other hand, the soil which has formed on top of the hill in recent times suggests that wind activity was reduced and vegetation gained the upper hand at a later date. This might indicate a return to slightly damper conditions, but evidence is not conclusive.

Pre-pottery Microlithic Occupation Phase (X).

The land surface which is indicated by the humus horizon at a depth of 4 ft. in the excavations of 1949 was occupied by man producing vast numbers of microliths, though apparently not using pottery. From the presence of the humus horizon at this level, not only at this site but also in several other localities, it seems probable that at the time a soil was being formed, in other words that the sand of the dunes was not moving. This implies slightly damper conditions than those obtaining before and after this period, with a cover of vegetation sufficiently dense to increase the humus content in the topsoil. At the actual occupation site man is likely to have contributed to this humus concentration. This phase is of particular interest from the point of view of primitive food economy. SANKALIA and KARVE (1949) have reported on the industry and the dolichocephalic skeletons found buried in layer (W) of our section, presumably from the land surface, horizon (X). Whether the grinding stones found in this industry are evidence of the use of grain remains to be seen, but this would not be proof of agricultural practices, since wild grass seeds are collected by Australian natives even today. The fauna associated with the site

comprises a rhinoceros of the *unicornis* group (represented by teeth and probably a shoulder-blade), a large bovine, a sheep or goat, deer, pig, horse, dog and what appears to be a mongoose, burrowing rodents, tortoise and fish. This fauna will have to be studied in detail. At the moment it is not certain whether or not domesticated species are included. The deer and rhinoceros are undoubtedly wild, the bovine, the pig and the horse could be either. The suspected sheep or goat is the only species which suggests domestication, but there are a sufficient number of wild ruminants in the fauna of Western India which have to be taken into consideration as alternatives. It is hoped that the investigation of the fauna can be completed at an early date. It will of course be necessary to check with care the levels from which the specimens came. It is quite conceivable, and in fact quite likely, that the pottery-making Neolithic to Iron Age inhabitants of level (Y) possessed domesticated animals. But if the existence of domesticated types in the pre-pottery microlithic horizon can be established we should have gained a most valuable piece of information about the food economy of early microlithic people of India.

The Dune Phase at Langhnaj (W).

The sands, layer (W), underlying the soil of the occupation floor of (X), constitute the body of the dunes. The definite shape of these dunes (as described above) is proof of their mobility for a considerable period. They rest, with their blow-outs, on a virtually level plateau surface. From the morphological point of view, these evidences of wind activity are so clearly superimposed on the general plain that one is inclined to regard the formation of the plain as a separate phase preceding the formation of the blow-outs and dunes. Unfortunately no section was available deep enough to cut through the floor on which the dunes rest. If in such a position a soil can be found, the suspicion will be substantiated that the phase of the formation of the dunes has to be separated from the preceding phases to be described presently. In order to allow for this possibility the letter (V) is tentatively assigned to this land surface.

Main Dry Phase (U).

The surface of the plains is underlain by a great thickness of sandy deposits. They are well exposed in numerous sections, mainly

in river cliffs and also in many nalas. The sand is of even grain, often calcareous, well-rounded and thus suggestive of wind activity. In the banks of the Sabarmati and the adjacent nalas it forms thick beds, occasionally with the distinct aeolin false-bedding, and on the whole extending with equal thickness over considerable distances. This appears to mean that the wind-blown sand was at least in part levelled out by water. The thickness of these sands varies but is always considerable. At Hirpura, for instance, it is about 30 ft. In places away from the river Sabarmati it appears to be much thicker. The tube well V-1 near Vijapur, for instance, contains as much as 95 ft. of this material.

The most characteristic section is probably that observed in the Sabarmati cliff at Hirpura. It is as follows (fig. 4):—

- (Z) 97 ft. 6 ins. above the dry season water level: Land surface with brown top-soil.
- (U) Wind-blown sand, purely aeolian in upper third with two horizontal sand-banks in lower two-thirds, with an indistinct stratification which becomes distinct near the base, where one or two lenses of material derived from (T) are evidence of water action. Total thickness 32 ft.
- (T) Red soil, very deep weathering, dark red near the surface, becoming lighter downwards. Near the base (about 20 ft. down) kunkar formations appear. Evidence of a land surface of considerable duration.
- (S) About 25 ft. (including the weathering horizon (T) of the material on which the soil developed: stratified river silts and sands, at the base passing into (R). They have the appearance of an inundation deposit and are sometimes called "alluvium". Palaeolithic industry.
- (R) Cemented river gravel. Mostly pebbles of about 5 mm. diameter, but also some larger ones, up to 1 ft. Components trap-rock, quartzite, granite and ironstone. Cement calcareous, probably an infiltration connected with weathering processes of (T). A Palaeolithic industry is present. Thickness at least 10 ft.
- (Q) An indurated clay, mottled grey and brown. Contains a

THE SABARMATI RIVER

fair amount of silt. Induration due to calcium carbonate.
At least 10 ft. thick.

This section, which is repeated in many other localities along the Sabarmati, suggests that conditions of aggradation were prevailing while the sands of (U) were being accumulated, at first with the aid of water, but with wind action becoming more and more prevalent until it dominates in the upper third. On the whole, therefore, this period must be regarded as a phase of considerable duration, starting with relatively moist conditions and ending with pronouncedly arid conditions. No fauna or prehistoric industries have been found in these deposits.

The Red Soil Phase (T).

The Hirpura section shows the aeolian deposits of (U) resting on a conspicuous land surface, marked by a red soil (T). The soil, which developed on calcareous river deposits (S), is a ubiquitous feature of the Sabarmati area and can be followed continuously over stretches of many miles. There is no doubt whatever that it is the product of a prolonged period of weathering under conditions more humid than those prevailing both before and after. The depth of reddening is about 25 ft.

A curious topographical point should however be noted. While this soil was forming the land surface in the Sabarmati area, covered with forest, the river cannot have been in the same place where it is today, at any rate, not in the plains where the soil is preserved *in situ*. Near the hills however, for instance at Hadol, the red horizon contains lenses of fragments of granite including fresh feldspar crystals. Here, the red bed seems to be in part laid down by water since, if weathering *in situ* was responsible for it, the feldspars would have been disintegrated. This section (fig. 5), therefore, indicates that at its exit from the hilly country the river maintained its position during the period of formation of the red soil. It appears that much red soil matter was washed into the river, where it was mixed with local granite detritus.

This bed at Hadol bears an interesting resemblance to the famous Bed III of Olduvai in Northern Tanganyika. The Olduvai bed has been regarded as weathering *in situ* by some authors but it, too, contains fresh feldspars and is more likely to be a water-deposit

(fluvatile or hillwash) in which derived soil matter is mixed with fragments of rock. On the Sabarmati, the sections prove the contemporaneity of this type of deposit with the period of soil formation. But soil formation and formation of water-laid deposits containing soil matter are not necessarily contemporaneous elsewhere, since a gravel containing older soil matter can be formed in any later phase. This alternative, too, is illustrated on the Sabarmati, in the section at Hirpura, where matter derived from the red soil is incorporated in the lower layers of the aeolian sands (U ; pp. 8-9).

The climatic interpretation of this buried red soil is interesting. From what has been said above, it is evident that at the present day red soils do not normally develop in this area, except on slopes in hilly country, where a forest cover has existed until recently. Similar calcareous red soils, however, occur farther south, for instance in the Dharwar and Bellary Districts, where they appear to represent the modern weathering in places which prior to interference of modern man, were covered with scrub and were reasonably well drained. The annual rainfall required for the formation of these red soils is quite low (18 ins. at Bellary). From this it is evident that in the Sabarmati area where the mean annual rainfall is about 29 ins., such red soils would, in all probability, develop at the present day over a much wider area than they actually do, if man, by replacing the natural vegetation with agricultural steppe, did not artificially make the soil climate more arid than it would be under natural conditions. The fossil red soil thus appears to suggest rainfall of the same order, *i.e.* about 20-40 ins., in a climate with a long dry season. There was certainly not enough water available to leach calcium carbonate out completely.

The River Silt Phase (S).

At Hirpura and in many other localities along the Sabarmati, the red soil developed on fluvatile sands and silts. With these deposits (for the sake of simplicity called River Silts) a phase of river activity came to an end which began with the deposition of the gravel (R). The total thickness of the gravel, sand and silt is over 35 ft. at Hirpura and the sequence—coarse material below, fine material above—is extremely consistent everywhere. It must, for this reason, indicate a raising of the river bed owing to aggradation, at a time when the

climate was becoming drier and the discharge of the river less. It is the usual picture presented by rivers in areas where the climate has changed from wetter to drier conditions, though the fact that coarse gravels are found at the base need not mean that the climate was very humid at the beginning. Coarse gravels are more usually indicative of seasonally dry climates in which occasional heavy floods provide energy for transport of the large pebbles. In humid climates there is a more or less even discharge throughout the year, and with intense chemical weathering the load of the river is usually of a fine grade and shows evidence of chemical disintegration. The Silt Phase thus indicates a drying up of the climate before the formation of the red soil, which in turn appears to indicate somewhat damper conditions.

The silts are the highest bed containing Palaeolithic implements. According to SANKALIA (1946, p. 30) finds were made at varying depths below the surface of the red soil. Since the weathering was a process which affected the river silt after it had been deposited, and since no implements were found on the surface of the red soil itself, all these implements are older than the soil phase (T) and contemporary with the aggradation of the silt phase, except for the relatively small number of rolled implements, which may be older. SANKALIA has classified the finds made according to 10 ft. levels and carefully analysed them from the typological point of view. He has pointed out that crude implements occur alongside more finished types which include Acheulian handaxes of latish appearance. There are also numerous flakes, but very few have striking platforms suggestive of Levalloisian technique. On the whole there is no distinct evolution from the older series to the later, and the main difference between tools of the gravel and those of the silt appears to be the absence of pebble tools which are so characteristic of the gravel. They are presumably lacking because sand and silt covered the river gravel. An important raw material was thus no longer accessible to man and this may well have had an effect on the industry. Moreover, cleavers are comparatively scarce. Since "cleavers" are functionally to be regarded as wood-choppers, their scarcity is possibly a direct result of the reduction of woods with increasing aridity. There is perhaps a slight improvement in workmanship as one ascends higher in the section,

culminating in three specimens from the upper river silt (SANKALIA, 1946, p. 102), but this is all. The lack of definite evolution of the industry confirms the geological observation that gravel and river silt are continuous deposits which correspond to a comparatively short period of increasing aridity.

The Gravel Phase (R).

At Hirpura the gravel bed which underlies the river alluvium is about 10 ft. thick. It is mostly a single bed, though occasionally divided by layers of silt or clay. This seems to be so particularly where the bed-rock penetrates the younger deposits. At Kot, for instance, where kaolinised granite appears, the gravel is interstratified with sand and silty clay (fig. 6). This section, taken as a whole, corresponds to our phases (R) and (S). It is separated from the modern river by a ridge of kaolinised granite. This shows that the river has, in places, changed its course since the period of the gravel phase (R).

Another section in which the gravel is divided occurs downstream from Kot at Ghoghadwanu Oghu, not far from Hirpura (fig. 6). Here it rests on mottled clay (as frequently elsewhere) and is subdivided by another bed of mottled clay into two portions. The lower gravel is composed, at its base, mainly of broken-up and more or less rounded ironstone fragments which are derived from lateritic crusts. It changes gradually into a gravel made up mainly of fresh bed-rock exposed by the erosion of lateritic crusts (see p. 16 and fig. 7). The upper gravel bed is of the ordinary type, containing numerous quartzite pebbles and being heavily infiltrated with lime. The sections exposed in this *nala* (Ghoghadwanu Oghu) are of particular interest as they show that the gravel bed was formed as the result of the denudation of ancient land surfaces. This point will be discussed later on.

As a rule, the gravel is cemented into a conglomerate by calcium carbonate. This is almost certainly derived from the overlying river silts (S) from which it was dissolved during the weathering period, (R). For this reason the cemented gravel forms vertical cliffs with good exposures which have yielded large quantities of Palaeolithic implements.

The industry, studied by SANKALIA (1946), contains a large variety of artifacts, from pebble tools of pre-Abbevillian appearance to refined Acheulian hand-axes, discoid cores and flakes of Levalloisian appearance. SANKALIA has made great efforts to sort out this assemblage and, on the basis of his material, come to the conclusion that it is a contemporaneous group. A large number of implements collected during the recent expedition are awaiting investigation. Several stratigraphical collections were specially made in order to find typological differences between the gravel beds resting on rock-benchés of different heights. Whilst at Pedhamli the preliminary sorting created the impression that the flakes and discoid cores were more frequent on the lower bench, a careful mapping and collecting survey at Luhar Nala produced specimens of late Acheulian appearance even from the upper benches. These preliminary (and therefore tentative) impressions obtained in the field would confirm SANKALIA's results of 1946. In view of the complexity of the situation, however, it will be necessary to study the newly collected material in the laboratory before a definite opinion can be formed. The undoubted presence of discoid cores and late Acheulian handaxes, ovates and cleavers makes one disinclined to regard this industry as early within Palaeolithic succession. It differs remarkably from the Sohan sequence of north-west India in the mixture of flake and core implements. It is perhaps, on purely typological grounds, most aptly described as a combination of late Sohan and middle to late Acheulian elements.

There is no evidence of a break between the gravel and the overlying river alluvium. The implements which SANKALIA found and described from the surface of the gravel, therefore, may be regarded as the last implements of the gravel phase or the first of the river silt phase. There was no land-surface at this level, except for a purely temporary one.

The Mottled Clay (Q).

In the vast majority of localities the gravel rests on a clay which is greyish, bluish or greenish, speckled with brown, or brown speckled with grey. It is often more or less cemented by calcium carbonate, which presumably is a later infiltration, probably the same as observed in the gravels. The physical composition of the clay is somewhat

variable. In most cases it contains a fair amount of silt, and sometimes of sand. In the neighbourhood of the granite hills, disintegrated feldspar grains appear occasionally and there is an admixture of quartz sand. Near outcrops of the Cretaceous, the mottled clay appears to be influenced by this parent material, quartzitic silts and kaolinitic clay matter making up the bulk of it. The speckling is evidently due to the partial oxidation of iron.

The stratigraphical position of this clay is clear. It underlies the gravel in depressions. Where the bed-rock rises and the gravel rests directly on it, the mottled clay is suppressed. It was, however, nowhere seen resting on an older Pleistocene or Tertiary formation, so that its relation to the older deposits of these epochs is obscure.

The mottled clay is not a weathering soil *in situ*. For this it is too well sorted. It is almost certainly a water-laid deposit of material derived from the decomposition of bed-rock in a climate with intense chemical disintegration. The absence of red iron compounds makes it resemble many of the Tertiary clays of Europe, some of which are associated with brown-coal deposits and which in all probability were formed in a warm and humid climate. But this does not mean that the period of deposition of the clay is contemporary with, or follows at all closely, the period in which the material was formed, so that the problem of the genesis of the mottled clay has for the time being to be regarded as entirely unsettled.

The Rock Bench of the Gravel Phase.

During the expedition an attempt was made to construct a longitudinal profile of the Sabarmati river and its terraces. In the process of this work it became apparent that the modern river is by no means in a graded condition, but contains several knickpoints. The most conspicuous we saw is caused by a ridge of granite pegmatite, at Madhuri, two miles downstream from Valasna. But it became equally apparent that the river of the gravel phase containing the Palaeolithic industry was not graded either. The sections of the mottled clay and cemented gravel just upstream from the knickpoint, at Sundarpur, about one and a half miles downstream from Valasna, illustrate this well. There is a large meander in the modern river, swinging to the left. Where it returns to the general direction of the river, the major

part of the knickpoint lies in a jumble of enormous granite boulders through which the water passes in several waterfalls. In the bend of the meander, which is completely covered by the river when in flood, the deposits of the river of the gravel phase are exposed, separated from the modern river by a bar of pegmatite containing veins of microcline, which were already known to BRUCE FOOTE. The situation is shown in fig. 8.

Upstream from the microcline barrier, cemented gravels rest directly on the rock. But downstream from it a brown sandy loam (mottled clay?) fills the depression between the rock, which dips away, and the cemented gravel, which continues horizontally. This situation suggests that prior to the formation of the loam there was a waterfall here. The river of that period continued to the west (on the right, looking down-stream) through a gap in the present barrier which is now covered by later sediments. Subsequently what appears to have been the pool of the waterfall was filled with the loam, and the gravel of the gravel phase (marking the beginning of the aggradation period) was deposited over both rock and "loam". Though sandier than the mottled clay and though containing some gravel seams, the "loam" is stratigraphically the equivalent of the latter. At Sundarpur it contains quartz flakes which perhaps are human artifacts.

At other localities also irregularities in the rock surface underlying the gravel and mottled clay are observed. Both upstream and downstream from Pedhamli, for instance, Cretaceous sandstone and shales form an uneven surface which in places bears an ironstone crust. In particular, about a mile upstream from Pedhamli the Cretaceous rocks form a barrier which the modern river has dissected in a canyon-like gorge. But during the cemented gravel phase this barrier seems to have formed a knickpoint, presumably with rapids. A flat rock bench of pre-cemented gravel age occurs here at two levels, 38 and 45 feet above the present river. Many other examples illustrating the uneven bench of the Palaeolithic river could be given.

The Pre-Gravel Phase Land Surface.

The earliest recognisable river phase was thus characterised by an uneven longitudinal profile with rock barriers. In addition there is evidence of numerous hills of bed-rock in the vicinity of the Palaeolithic

river, which were gradually drowned in deposits, as aggradation proceeded during our phases (R) to (U). Several examples have been given of such buried hillocks, for instance, at Kot, (fig. 6). They become more frequent as one advances upstream and approaches the hills at Hadol, where the present land surface, with its alluvial flats and its crystalline hills, reproduces the picture that was obtaining farther downstream in Palaeolithic times.

Since the Sabarmati flows from north to south not far from the eastern border of the great depression between the Kathiawar Peninsula and the trap and crystalline massives of Central India, it is not surprising to find a drowned, hilly, land surface of Palaeolithic age. This land surface is, however, of special interest because it is associated with a type of lateritic weathering. The age of the periods of lateritic weathering has yet to be determined in India. When it has been done some of them will undoubtedly play an important part in the chronology of the Indian Old Stone Age. For this reason the following observations are being put on record.

Lateritic Weathering.

The general appearance of the weathering profiles is indeed of the type which is commonly called laterite, with cellular crusts of ferric hydrate concentrated below the surface. The use of the term now tends to be restricted to the crust texture, but the weathering process which takes place in such soils is variable. Broadly speaking lateritic soils are soils of the allitic type with superficial concentration of sesquioxides in the form of crusts and concretions. Allites are soils from which the silica has been removed with a consequent enrichment in alumina, culminating in the important aluminium-ore, bauxite. On granite and other rocks rich in silica, the de-silification often does not go beyond the kaolinite stage [$\text{SiO}_2 : \text{Al}_2\text{O}_3 = 2 : 1$]. On basic rocks (KRISHNAN, 1935) it usually proceeds further, and all silica might disappear, Al_2O_3 only being left (together with Fe_2O_3). This is allite in the strict sense of the word. Alumina sufficiently pure for commercial purposes is called bauxite. Since iron, as one of the sesquioxides, moves relatively freely in these soils and is concentrated in the crusts and concretions near the surface, an iron-red colour is characteristic of lateritic cementation.

It has not yet been possible to carry out a full chemical investigation of fossil soils in the Sabarmati area, but there are indications at Kot that the suspected laterites do in fact tend in the direction of allites. At this locality granite is the fresh bedrock on which buried soils of lateritic appearance are found. The feldspar of the granite is mainly orthoclase, with a proportion of silica to alumina of 6:1. This granite bears a disintegrated crust which turns into a completely softened mass of white clay with quartz crystals. In places this has been washed and sorted by natural agencies and a pure white clay has been deposited. Both this clay and the clay obtained by washing from disintegrated granite are worked for kaolin in the neighbourhood and an analysis was kindly put at my disposal by the managers of the Sorab Dalal China Works, Ransipur. From it the molecular silica/alumina ratio can be calculated as being 1.85: 1. In the kaolin crystal, the proportion is 2: 1. Since the clay from Kot is likely to contain some finely-divided quartz mechanically derived from the granite, the Si/Ac ratio of the quartz-free clay is probably lower than indicated by the analysis.

This suggests that in the clay from Kot (which from the practical point of view is exceedingly pure) the removal of the silica has just passed the kaolin stage, so that some free alumina is already present. Kaolin has indeed been regarded by HARRASSOWITZ and others as an intermediate stage in the process of lateritic weathering, though more recently the view has spread that kaolin is the end-product in granite districts. Taken as a whole, the evidence from Kot suggests that the soils under discussion may be classified as lateritic. At Kot superficial iron crusts are found in many places and they occur also beneath the cemented gravel, as they do at another important occurrence of lateritic soils about half a mile upstream from Pedhamli.

At this locality the soil rests on Cretaceous red and white sandstones and shales containing white mica and disintegrated grains of feldspar, as well as white clay, the constitution of which has not yet been determined. The lateritic soil is about 15-12 feet thick and shows no distinct zonation, except that crust-formation and horizons of iron-stone concretions are embedded in the clay in the upper levels. Along the joints disintegration extends downwards. This profile is overlain

by the usual cemented gravel with its calcareous cement and numerous calcareous concretions.

Lateritic sections exposed in vertical cliffs often exhibit conspicuous crusts which, however, are merely superficial. They are produced by the drying out of the cliff face, which draws the soil solution to its exposed surface, where the iron is irreversibly coagulated. It is necessary therefore to check the profile by removing the superficial crust with a pick before any of the sections are noted down and samples taken. The formation of these superficial crusts appears to be a widespread phenomenon in the tropics. Wherever iron solutions are moving in the soil crusts or concretions form when evaporation takes place.

Murram is commonly formed in this way and so are the bog-iron ores deposited in places where there are seepages from the water-table. The property of certain soils covered by lateritic crusts which allows them to be cut when fresh and to harden when exposed to air (which makes them so useful as a building material) is due to the same cause. I first noticed the phenomenon of crust formation on cliff faces when studying the section of the Olduvai Gorge in Tanganyika, where the external appearance of the section simulates a true laterite whilst behind the crust a feldspar-bearing sandstone with a red matrix was exposed.

Another point has to be borne in mind when lateritic soils are studied. This is the distinction between derived laterite and laterite *in situ*. The iron concretions and the clay composing the upper horizon of lateritic soils are very liable to be washed about by sheet-floods in the monsoon period, since the crust formation is inimical to vegetation and the surface exposed to the direct impact of rain. Vast quantities of lateritic material, therefore, are washed down the slopes and they form thick deposits of *derived* or *colluvial* laterites in the depressions. This phenomenon is of great importance in connection with the Stone Age industries of the Madras region and will have to be studied closely in that connection. There is some derived laterite at the base of the cemented gravel in the Sabarmati area, for instance in the cliff face opposite Derol at the lower end of the gorge described by FOOTE. In rivers lateritic crusts are converted into ironstone pebbles. Pebble beds of this type form the lower part of the cemented gravel at Ghoghadwanu

Oghu. As this is only a mile or two downstream from the locality opposite Derol, the derivation of the ironstone gravel from the described "detrital laterite" is very obvious.

Block Accumulation in Tropical Countries.

As one approaches the river near Ransipur (Virpur), the general land surface (V) is followed by a slightly lower terrace level. From it one descends into the valley of the Sabarmati, passing a vast accumulation of large blocks of granite and of a coarse quartzite conglomerate which lies at a somewhat higher level and must have formed the covering of the granite. These blocks are derived from the rock *in situ*, and were detached and rounded off by some agency other than water. It can be seen that the original shapes of these blocks were determined by the coarse jointing. Such block accumulations are observed in many parts of the tropics and their origin has usually been ascribed to physical weathering of some kind, although it has rightly been pointed out that the effects of insolation do not reach to a depth sufficient to detach such blocks. The evidence at Ransipur and the neighbouring locality of Kot suggests that the formation of giant blocks or boulders is closely related to the process of spheroidal weathering (e.g. HOLMES, 1944. p. 118, pl. 25) which is due to the penetration of chemical weathering along the intersecting joints. The "boulder field" of Ransipur continues downstream to Kot where blocks of granite measuring 30 and more feet across are embedded in decomposed granite. Here it is possible to see that the disintegration followed the joints. Deep-reaching disintegration penetrating along the joints is characteristic of kaolinitic weathering, so that the isolation of large boulders here is closely comparable with the isolation of smaller blocks in the case of spheroidal weathering, as observed even in temperate climates. At Ransipur the disintegrated material has been removed by the floods of the river and residual boulders are left lying about in a conspicuous manner. In other places, especially on hills, the disintegrated material has been removed by rainwater after the destruction of the vegetation cover protecting the soil.

Climate of Laterite Formation.

The climatic conditions required for the formation of laterite are as yet not known in detail. Most workers now agree, however, that

a climate with a dry season is necessary in order to bring the solutions containing the sesquioxides to the surface. HARASSOWITZ (1926) has elaborated this aspect. During the wet season excess water drains down through the soil to the water table, which may be very low. During this period solution prevails, silica is removed at a fast rate and so are the alkali constituents. During the dry season the less mobile sesquioxides come to the surface under the influence of evaporation. Actually it is not necessary to assume a movement of the sesquioxides on a large scale, since the removal of the silica and alkalis in the wet season would lead to a concentration of colloidal sesquioxides in the upper horizon of the soil. When these dry out, however, the iron hydroxide and other sesquioxides lose their water and concretions are formed which do not revert to a colloidal state again when moistened in the following wet season.

It is easy to conceive of an allitic soil developing in the tropics under seasonally damp conditions, or wet conditions throughout the year, under a cover of woody vegetation. It is known that many tropical soils tend to be allitic. If, as the result of natural agencies, de-forestation occurs, such soil is exposed to intense drying up and lateritic crusts and concretions will inevitably form in its upper horizons. As an alternative to the usual view that in laterites the B-horizon lies above the A-horizon, it is therefore possible to explain the weathering profile as an A-horizon partially concreted by drying up, whilst the B-horizon in the ordinary sense is absent altogether.

It would appear that on the whole lateritic soils require a somewhat ample rainfall to effect the removal of the alkalis and silica. There is no evidence of deep allitic or lateritic weathering in active progress in the drier parts of India. Everywhere the "lateritic soils" appear to be fossil. Perhaps laterite is still being formed from the Konkan southwards to Travancore, but I was not able to visit that region.

In drier climates the earth-alkalis, especially calcium, are not washed out but form concretionary B-horizons or are evenly distributed throughout the profile. This appears to be the type of soil which would form today in Northern Gujarat. It may be assumed, therefore, that lateritic weathering, accompanied by kaolinization in the subsoil, indis-

cates wetter conditions than those obtaining in Northern Gujarat at the present day. The "lateritic soils" of Kot, Pedhamli and other places are therefore taken to indicate relatively humid phases.

Age of the Lateritic Weathering.

On the grounds of the stratigraphical sequence at Kot, Pedhamli, Derol and so on, the lateritic phase of the Sabarmati may be placed immediately prior to the formation of the mottled clay. This is its latest possible date. Rolled fragments of lateritic crust have been described above as occurring in the cemented gravel and the lateritic weathering profiles occur *in situ* below the cemented gravel, for instance at Pedhamli and Aglod.

As to the mottled clay, this, too, appears to be later than the lateritic weathering. If it was younger, one would expect to find red weathering on the clay surface, which has not been observed so far. From this point of view, therefore, the mottled clay, as seen in the sections in the valley of the Sabarmati, would be later than the laterite. On the other hand well-borings in the neighbourhood of Vijapur have revealed several layers of "mottled clay". The lateritic weathering may well be older than all of them. In this case it might be considerably older than the cemented gravel phase, and there would be a gap of an unknown duration in the record of the Sabarmati cliffs.

It is perfectly possible that the lateritic weathering is very much older than the Pleistocene beds considered so far. Some workers regard the laterite altogether as a Tertiary formation. Red soils of lateritic appearance occur between the sheets of trap lava on the Deccan Plateau. The Cretaceous sandstones and shales of the Sabarmati area appear to be the products of kaolinitic weathering, which again may be taken as a possible indication of weathering of lateritic type. In this case however, it would be difficult to distinguish a deposit of kaolinised material from kaolinization after deposition. The view, therefore, that the lateritic weathering of the Sabarmati sections is as early as Mesozoic is thus tenable.

In short the age of the lateritic weathering remains a problem. It is, however, possible that it occurred immediately prior to the formation of the mottled clay and cemented gravel and that it is contemporary

with the formation of the buried pre-Palaeolithic land surface. It is certainly not later than this.

Unconsolidated Deposits Revealed by Well-Borings.

Thanks to the courtesy of the Public Works Department of Vijapur, the Tube Well Company of the Union Engineering Corporation, Ahmedabad; and the Public Works Department of Baroda, I have been able to study large numbers of records of well-borings made in Northern Gujarat and also samples from some of them. These borings will have to be discussed in greater detail on a future occasion. In the present context, however, it is necessary to mention a few points arising out of this evidence.

(A) At least three miles from the river some of the well-borings suggest that the sequence of deposits is the same as in the banks of the Sabarmati river, with the red weathering horizon (T) and the cemented gravel (R).

(B) In several borings, murram layers have been reported. The term "murram" is used in the records for any kind of iron concretion. The descriptive details suggest occasionally that lateritic crusts may have been struck, so that these borings deserve to be studied in detail. It is conceivable that they might provide additional information about the age of the latest phase of lateritic crust formation in Northern Gujarat.

(C) In the Vijapur area the sequence of deposits continues to a depth of over 200 feet (Wells F. 1 and F. 3) without striking the solid. Twenty-two miles south-west of Ahmedabad at Chaloda an artesian well was sunk to a depth of 846 feet through alternating layers of sand and clay, without reaching the solid. The land surface is 85 feet R. L. This well, therefore, shows that the same sands and clays which make up the topmost 100 feet of the ground of Northern Gujarat continue to a depth of more than 761 feet below the present sea-level. It seems difficult to explain this by means of eustatic fluctuation of the sea-level. It would be just possible to relate the lowest stratum in this boring to the lowest Pleistocene sea-level, which is commonly assumed to be in the neighbourhood of 670 feet. Unless one is prepared to admit an even greater drop in sea-level, the conclusion is inevitable that Northern Gujarat is an area of comparatively recent tectonic depres-

sion. Structural considerations are known to support this conclusion.

Stratigraphical and Climatic Succession in the Sabarmati Area
(Summary).

All geological deposits here discussed are later than the formation of the Deccan Traps, which must at one time have been continuous from Gwalior to Kathiawar. A tectonic graben or basin must have been formed, or have started to form, after the early Tertiary, and in this depression the Sabarmati drainage system came into being. The earliest part (and in terms of time, by far the longest) of the history of the filling is still obscure, although the well-borings afford a few glimpses of it. It is possible that the Sabarmati has shifted its course slowly to the east, where we pick it up at the time of the lateritic weathering (P). From this period onwards, the evidence suggests the following succession of deposits and climatic phases.

- (P) Allitic weathering and formation of lateritic crusts. Climate more humid than at the present. A hilly land surface.
- (Q) Mottled clay deposited in the basins of the river bed. First evidence of the Sabarmati river being in the area where it flows today. Climate not of the lateritic type.
- (R) Cemented gravel phase. The river carries coarse pebbles and deposits them as a sheet, veiling the uneven bench and the basins filled with the mottled clay. Climate characterised by seasonal floods, precipitation apparently somewhat heavier than nowadays. Palaeolithic man present in the area.
- (S) Silt phase. The river builds up its bed by shedding sands and silts. Climate becoming drier, run-off decreasing, and the river as a result building up its bed to form a steeper gradient. Palaeolithic man continues to be present.
- (T) The red soil phase. The aggradation having drowned part of the ancient land surface, the river has been able to shift its bed, presumably to a more westerly position. A red soil is formed, covering the exceedingly flat new land surface formed by the aggradation. Climate probably more humid than previously, with dry forest or scrub covering the country. The climate was, however, less humid than during

the lateritic phase (P). Palaeolithic man vanishes from the scene.

- (U) Main dry phase. Once more the river begins to aggrade, raising its bed still further. It re-appears in the area of the present river and lays down fine silts and wind-blown sand derived from the arid land surface away from the river. Gradually river action becomes less conspicuous and aeolian deposits of sand begin to dominate. The upper part of this bed appears to be purely aeolian in most places. Climate becoming drier again and culminating in an arid period.
- (V) After the end of the dry phase, a flat land surface was either left or (more probably) formed by sub-aerial denudation. Apparently a phase of somewhat damper conditions, though no soil has been found in the Sabarmati area (but see the Mahi river p. 26).
- (W) Dune phase. More or less isolated dunes are blown over the land surface (V). Climate: a revival of drier conditions.
- (X) Pre-pottery microlithic phase. A soil develops on the dunes. Man re-appears as the maker of microlithic tools.
- (Y) Latest dry phase. This phase is of a somewhat doubtful character, as it may either be due to a slight increase in aridity of the climate or to man's destructive influence on the natural vegetation. Pottery makers present, agricultural activities highly probable. Up to Iron Age.
- (Z) Modern phase. Climate like that of (X), with a prolonged dry season but sufficient precipitation to maintain (under natural conditions) soil formation by chemical weathering under cover of a dry forest or scrub. Period of present-day agriculture.

It will be noticed that this sequence of alternating damper and drier phases, on the whole, shows a trend towards greater aridity as one approaches the present day. Its significance will be discussed in the concluding paragraphs on p. 42.

The Age of Stone Age Man in Gujarat.

The sequence of climatic events revealed by the deposits here

discussed, appears to be sufficiently complex to represent a very considerable period of time. Whilst the microlithic phases are certainly quite late, i.e. either early historic or near the end of the prehistoric period, the Palaeolithic deposits, separated from them by a great thickness of strata and at least two periods of a weathering of land surfaces, suggest extreme remoteness. It is certain that the Palaeolithic industry dates from well within the Pleistocene. The determination of its actual age, however, depends on the possibilities of correlating the climatic succession of the Sabarmati with that of other areas, notably of Kashmir and Northern Punjab. We shall have to return to this question later.

III. THE MAHI RIVER

One group of sections visited on the Mahi River lies about 100 miles south-south-east of those on the Sabarmati, close to the railway bridge near Vasad, about 15 miles north-west of Baroda. The second group is at Dabka, 20 miles downstream from Vasad. Vasad had been visited before by SANKALIA (1946, p. 60) who found microlithic sites on the surface. An undoubted palaeolith was also found in 1941-42 Expedition (SANKALIA, 1946). The gravels in the river cliff were searched for Palaeolithic artifacts, but none were found. There is no reason whatever why the Mahi should be barren and it is desirable that further searching should be done.* The sections were of the greatest interest from the chronological point of view, as they exhibited a sequence which is closely comparable with that established for the Sabarmati. The lower Mahi is still within the great basin of Northern Gujarat.

Over a distance of a mile upstream from the railway bridge on the left bank of the river, six sections were measured and recorded. Section I, near Raika village, the farthest upstream, was as follows (fig. 9):—

- (Z) Surface soil.
- (W) Wind-blown sand, forming a slight hillock on the plateau surface.
- (V) Land surface of the plateau with a brown soil.
- (U) About 35 feet of yellowish-brown sandy silt with kunkar concretions and of aeolian appearance. Wind activity seems to have prevailed from the lowest horizons upwards. If this is at all significant it means that the river was less active here than on the Sabarmati.
- (T) Slightly reddish zone with kunkar. Section II shows this to be a reddish soil which becomes paler downwards. It

*This has been started by Dr. B. SUBBARAO, on behalf of the M. S. University of Baroda. A few well made handaxes etc., have been found by him. (H. D. SANKALIA).

THE MAHI RIVER

rests on yellowish-brown silt, but in both sections I and II the actual contact between (T) and (S) was obscured by talus.

- (S) Brown silt with layers of kunkar, especially in the lower 8 feet. Thickness, including red weathering (T), about 37 feet. Apparently a fluvial flood loam.
- (R) Cemented coarse sand and fine gravel, in places with pebbles of kunkar. 12 feet. In sections II and III, this gravel bed is divided into three by beds of clay with kunkar.
- (Q) Mottled clay impregnated with lime. 15 feet. At water level there appears another bed of gravel.

This sequence of deposits closely resembles those of the Sabarmati, for instance at Hirpura. The red soil divides the section into a lower part, which is mainly fluvial, and an upper part, mainly aeolian. Even the total thickness is of the same order. The land surface (V) is 101 feet above the dry season water level (compared with 98 feet at Hirpura). The red soil is an even more conspicuous feature in the section at Dabka.

The following differences, between the Mahi and Sabarmati, may be noted. There appears to be a series of alternating layers of mottled clay and gravel at the base of the Mahi sections, instead of the single gravel bed resting on the mottled clay as observed in most of the Sabarmati sections. It shows that the formation of these clay beds is intimately connected with the gravel phase. Presumably they are still water deposits laid down in cut-off portions of the river. The gravel phase is followed by the usual fluvial silt which is richer in calcium carbonate in the Mahi. This difference is perhaps due to the larger amount of calcium available in the rocks from which the Mahi alluvium is derived, namely the trap, compared with the granites, quartzites and sandstones of the Sabarmati catchment area. Following the phase of red weathering, sands and silts were deposited which correspond closely to those of bed (U) of the Sabarmati. It is possible that they are divided by a blackish soil, but since this horizon was inaccessible I can do no more than point out this possibility in the hope that future investigators might find a spot where samples can be taken.

An important feature of the Mahi is the presence of a soil or

land surface (V), which has not been observed on the Sabarmati. This soil and the modern one are blackish-brown in colour. Fig. 9 shows sections I and II of the Mahi near Raika. They illustrate the amount of variation to be observed in the sequence in this area.

From the point of view of climatic chronology it is evident that the sequence of events on the Mahi was the same as on the Sabarmati. No climatic differences are indicated. The laterite phase (P), however, is not represented on the Mahi, probably because the solid is not exposed.

IV. THE LOWER NARBADA SYSTEM

(a) *Orsang River.*

The Orsang is a tributary of the Narbada. Sections were studied about 35 miles east-south-east of Vasad and about 25 miles west of Baroda, at Bahadarpur on the right bank and Sankheda on the left. About 13 miles upstream from Sankheda the Orsang leaves the crystalline rocks underlying the Deccan Trap, and it flows as far as Sankheda in a rapidly widening alluvial channel. Near Sankheda it is about 10 miles wide. This area was already known to BRUCE FOOTE as a prolific site yielding microliths (1916, p. 135). FOOTE also noticed that fossil bones occurred in the gravels, but the discovery of an interesting Palaeolithic industry is due to SANKALIA (1946, p. 44).

The sections in the banks of the Orsang are somewhat more variable than those on the Sabarmati and the Mahi, but basically the sequence is still the same. In fig. 10 three sections are reproduced of the right bank of the Orsang, near the mouth of the Kundyā Nala. It is here that the palaeoliths were found. The figures show that the general sequence, of a silt or clay at the base, fluvatile sand and gravel, a period of red weathering, a period of fluvatile sands changing upwards into aeolian deposits, is present again. But the entire sequence is only about 50 feet thick. There is considerable variation in the beds below the red soil. In places (e. g. right part of Section II, fig. 10) there is a cemented gravel overlain by sand, but the sands and gravels are irregularly deposited, forming thick beds in places and thinning out elsewhere. There are parts of the cliff which are sandy throughout, whilst in others gravel dominates right up to the red weathering. Moreover the gravel is often loose. In Section I, where the gravel produced palaeoliths, the weathering has stained the gravel red. But the investigation of the section revealed that there is, at this place, hardly more than an iron-staining present. This alone would not justify the assumption that the reddening corresponds to a period of weathering, but on the opposite (left) bank, in the cliff below the junction of the Unchh, the red soil occurs on silt and gravel *in situ*. Samples were

collected from this section and they will have to be analysed. It is probable that the weathering is of the same type as the red weathering of the buried soil (T) of the Sabarmati. It is not of the lateritic type.

The upper series begins with lenses of gravelly clays in places, and in others with fluviatile sand. They correspond to the lower part of period (U) of the Sabarmati. The upper part is distinctly aeolian, though with one characteristic difference: the aeolian silt component is far more conspicuous than on the Sabarmati and the Mahi. Some of these silts, for instance on the left bank, may almost be described as sandy loess.

The top soil is black and about 8 feet thick with a pale leaching horizon of about 1-2 feet on top. On inclined surfaces the soil tends to be brown.

From the typological point of view, the Orsang industry is identical with the Sabarmati Palaeolithic. Many of the implements are rolled but, in a river gravel, rolling need not imply a much greater age. SANKALIA found no typological differences between the fresh and the rolled groups.

The stratigraphical sequence of the Orsang Valley and its climatic implications are thus as follows:—

- (Q) (R) (S). A period of river activity. Deposition of mottled clay, or its equivalent, seems to me more prevalent in the lower part of the series, but beds of clay, sand and gravel follow each other in varying combinations, both vertically and horizontally. Climate: probably a period of decreasing river activity since the river was aggrading, but even in the final stage of this period more water appears to have been present than in the Sabarmati.
- (T) Period of red soil. Climate: more humid than previously, a dry forest climate, as on the Sabarmati.
- (U) Revival of river aggradation passing into aeolian phase. Dune sands beside fluviatile sands. Also loess-like silts. Since loess is deposited at a greater distance from the area of aeolian deflation than are sands, and since loess requires suitable vegetation (steppe) to catch the wind-borne dust, it may be inferred that the Orsang was nearer the margin

of the dry zone than the Sabarmati during this dry phase. It is possible that this period has to be subdivided. On the Sankheda side a faint indication of a greyish-brown horizon, possibly due to weathering, is seen in the series. But the one or two dry epiphases (W and Y) of the Sabarmati have left no clear trace in the Orsang sections investigated. This may again mean that the climate was slightly damper than on the Sabarmati and just able to prevent the blowing about of the sand during phases W & Y. (Z) The modern soil, indicating a return to somewhat damper conditions after the end of the aeolian phase.

(b) *The Narbada at the Mouth of the Orsang.*

A short visit was paid to the cliffs at Chandod. A little distance upstream from this town the Orsang joins the Narbada as a right-hand tributary. The section was plotted over the distance of about a mile, comprising the cliffs from Chandod upstream to the mouth of the Orsang and thence up this river. There was no time to measure the sections, nor to study them in detail. It became evident, however, that this area deserves a close study. Several observations could be made which have a bearing on the history of the course of the river and would help in interpreting the stratigraphy both of the Karjan and the upper Godavari. For this reason the sections are recorded here (fig. 11), although the observations must be regarded as of a preliminary character.

Chandod lies about 13 miles downstream from the exit of the Narbada from the gorge in which it has cut through the Western Ghats. The Deccan Trap, therefore, supplies much of the material of the river. The Orsang brings rock from the crystalline complex and there is also a batch of the Cretaceous Bagh Series upstream from the mouth of the Orsang, supplying sandstones and limestone. The dark colour of the gravel beds, however, suggests that the trap component is dominant. This applies even to the cliff up the mouth of the Orsang where, in all probability, the Narbada invades the alluvial funnel of its tributary during the period of floods.

The section is not exposed right down to water level. There is a low alluvial terrace present, which on the Orsang consists of sticky

clay of very recent origin, and on the Narbada of sand. This level is connected with the present seasonal regime of the rivers. In addition there is on the Orsang a step in the cliff which consists of loose black gravel and sand. It reaches to about 15 feet above the level of the mud-bank and is probably plastered against the older, erosional cliff (fig. 11, "cross-section"). If this is correct the gravel suggests a late aggradation period after the formation of the main cliff. This gravel has provided no clue to its age. It may be Pleistocene but the possibility of its being Holocene must be kept in mind. The gravel is blackish and apparently the product of the Narbada, not of the Orsang.

The main cliff contains stratified silts and sands in its upper part. There is no question here of aeolian deposits. In comparison with the Sabarmati and Mahi, water activity here has been more intense throughout. Below this upper silt and sand an older series occurs in the Orsang. It consists of silts, sands, and gravel which, as seen in Section IV of figure 11, are distributed in a peculiar way suggesting a fault and a sinking away of the left-hand part of this section while the deposition of the upper sand and silt series was in progress. At the disturbance itself the upper beds dip so steeply (the sketch, section IV, is not exaggerated) that it is somewhat difficult to hold the alternative view, namely that fluvial sand and silt was shed over a pre-existing cliff. In the right-hand part of the section too, the gravel beds have a dip which is considerably steeper than is usual in fluvial deposits. In this connection it is worth while to record that as long ago as in 1869, speaking of a locality near Broach, some 35 miles downstream from Chandod but also lying near the escarpment of the trap and the sedimentary complex underlying it, BLANFORD (p. 72) said: "The alluvium which forms the cliff along the river banks was not only much consolidated. . . but the beds in places were seen curved as if disturbed. . . all of these alluvial deposits require a more careful and thorough search and examination for indications of their origin. . . . Enormous tracts are covered by them, they are the richest and most thickly populated districts of the country and they are eminently deserving of study, if only for agricultural purposes, for upon their distribution depends, to a great extent, the kind of grain grown and consequently of food consumed by the people of the country. But their

geological history is still very obscure." This call for increased work on the Pleistocene deposits of India has still not been answered. It illustrates that in those remote days of Indian geology, the importance of the study of superficial deposits in the interests of the food economy of the country was perhaps more clearly realised than it is today. The expedition of 1949 was probably the first officially supported expedition examining deposits of this kind. Its purpose was largely historical, i.e. the changes in environment and their co-ordination with the technological evolution of early man were to be studied. But it is worth while to point out that such work supplies a wealth of information of potential economic interest to modern man.

Returning to BLANFORD's point, he appears to have observed disturbances comparable with those found by us at the mouth of the Orsang.

On the Narbada (fig. 11, V, VI, VII), the sections comprise bedded sand below a bed of gravel, about 15 feet thick in the middle, and the stratified silt and sand on top.

It is impossible to interpret this series without further study on the spot. It appears that three complexes are present, namely (a) an older complex of sands and gravel, (b) an upper complex, apparently starting with gravel but mainly composed of sand and silt and (c) separated from these two by a period of erosion, an aggradation of gravel, which is perhaps relatively recent.

These sections indicate that water has played an even greater part in the formation of the deposits at Chandod than it has at Sankheda. It appears that, proceeding south-eastwards, one is leaving the region of wind action, to which the Sabarmati belongs. The second point of interest is that an *emboitement* has to be reckoned with, i.e. the deposition of river deposits at the same height above the present water level in successive periods of aggradation, separated by periods of erosion.

(c) *The Karjan River Near Rajpipla.*

About seven miles south of the Narbada at Chandod, the city of Rajpipla (Nandod) is situated on a large meander of the Karjan river, which is a left tributary of the Narbada. The Karjan comes from the Deccan Trap the escarpment of which lies only two or three miles

upstream from the town. No disturbances of possibly tectonic origin were observed in the sections which, for this reason, are more intelligible than those at Chandod. Moreover, the river deposits at Rajpipla have produced Palaeolithic implements, which have been described by SANKALIA (1946, p. 317).

The sections on the left bank of the river, west of the town near Sajva village, are cut into an exceedingly flat terrace, the height of which varies from 156 to 164 feet R. L., which is about 100 feet above river level. They show (fig. 12) consistently two sets of deposits. The lower one rests on mottled clay, consists of stratified sands and finishes with a brown clayey horizon which looks like a soil. Samples have been taken for analysis. This horizon is extremely persistent and has the consistency of clay like a modern cotton soil, though its colour is chocolate-brown instead of black. The second set begins with a gravel or with sand. The upper part of the sand is either replaced by a blackish gravel or interstratified with it. A black soil, possibly, a cotton soil, forms, the modern surface.

It is noteworthy that the suspected buried soil is less high above the water level farther upstream. At Hanumanjino Nala its surface is 60 feet above water level, at Sajva it is 45 feet and on the right bank at the ghats of Rajpipla town, about 26 feet.

The two sets of deposits are curiously reminiscent of the two sets, separated by the weathering period (T), observed in the Sabarmati, the Mahi and the Orsang. One is tempted, therefore, to identify the suspected buried soil with the red weathering of the Sabarmati. If this can be substantiated it will mean that a regur type of weathering was prevailing in Rajpipla. Whether the unbedded sands of these sections contain aeolian material remains to be seen.

On the right bank of the river immediately below the houses of the town, the section is only about 60 feet high. It differs from those near Sajva in having a cemented gravel at its base and in being gravelly throughout up to the deep-brown, clayey, supposed weathering horizon. This in turn is covered by fine yellow sand which appears to be aeolian, and a coarse black gravel caps the section. The lower set of deposits is here entirely fluvial, though the fact that aggradation took place suggests that the climate was becoming drier after the formation of the

brown clay and the land surface on it, apparently much more like period (U) of the Sabarmati sequence. The final episode, however, is different; coarse gravel spread over the surface of the sands in a sheet-like fashion. This is very obvious if one combines the Rajpipla sections with those of the western side of the river, whose valley cannot at that time have been in existence. The gravel deposits appear to have been formed by floods coming from the near-by mountains during a period when a good seasonal supply of water was available, but when the climate was sufficiently arid to prevent erosion. It is a common phenomenon that a river loses water in deltaic fans at the foot of mountains. Decrease in water volume means that the gradient has to be steepened by aggradation to maintain the flow. The top gravels at Rajpipla, therefore, would be regarded as evidence of comparatively dry conditions, and of a climate drier than the present. The widely-held view that coarse gravels need a wet climate and, therefore, a pluvial, is certainly erroneous. If the preceding sand phase means conditions of great aridity, then the aridity of the top gravel phase was certainly somewhat less. But its climate must not be regarded as humid.

Greater humidity after the formation of the top gravel is indicated by the deep black soil of the land surface and the down-cutting of the river.

As one proceeds upstream on the left bank of the river from the sections at Sajva, the sequence remains essentially the same until the cliff becomes overgrown. A large tributary nala joins the river, and upstream from it other cliffs begin. They soon become precipitous and show a sequence very different from that observed further downstream. At Ringniki Dhol, the lower third of the cliff, which may be about 100 feet high, is composed of solid, brown, greasy clay. Sometimes it is mottled and kunkar nodules are present in it. Near river level the clay contains pebbles in places. Most of these are angular. They cannot have suffered much transport. The higher part of the cliff, which was not accessible, also consists mostly of clay but apparently interbedded with sand.

This section is so different from those described previously that there is perhaps a disconformity hidden near the mouth of the nala which separates the Sajva area from that of Ringniki Dhol. The only

point of resemblance between the two is that the clay of Ringniki Dhol is somewhat like the thin layer of clay in the Sajva and Rajpipla town sections which have the appearance of a fossil soil. It is possible that the material of this supposed soil is really derived from the clay mass exposed at Ringniki Dhol. But it is equally possible that the clays of Ringniki Dhol are an accumulation of clay derived from cotton soils and deposited in water.

These clays assume some importance because they appear to be very similar to the clays found on the middle Narbada, which are connected with the famous implementiferous and fossiliferous Pleistocene sequence of Hosangabad and Narsingpur. These latter deposits are separated from the lower Narbada by a long gorge-like pass through the trap mountains. But it is conceivable that at the foot of these mountains clays were deposited, the material of which was derived from cotton soil weathering somewhere upstream in the same river system. BLANFORD (1869) emphasised the close resemblance of the clays of the lower Narbada to those of the middle Narbada. As I have not been able to visit the latter area I can only accept his statement. At Ringniki Dhol the clays would appear to belong to an older series than do the gravels and sands of the Sajva and Rajpipla town sections. The latter would constitute the filling of a valley cut into this clay.

The conclusions to be drawn from these observations on the Narbada system, at Sankheda, Chandod and Rajpipla, are admittedly tentative. The evidence is clearest at Sankheda, for the same two cycles of increasing aridity were found as on the Sabarmati, separated by a fossil soil. The entire sequence, however, appears to have been preceded by the formation of large quantities of brown clay, and these clays might in the future afford a link with the deposits of the middle Narbada.

V. THE UPPER GODAVARI SYSTEM.

Some observations were made about 130 miles south-south-east of Rajpipla, on the upper Godavari system in the area of Niphad, not far from Nasik. Unlike the river systems considered so far, which all drain westwards into the Arabian Sea, the Godavari crosses the Indian Peninsula to flow into the Bay of Bengal. For this reason the rivers near Nasik flow on a mature land surface which has been denuded to an almost flat plateau with a few isolated inselbergs. In spite of the maturity of the landscape, however, the profiles of the rivers are not graded and they present many knickpoints which indicate shifting of the river bed in Pleistocene times. Moreover, the bed of the river is in the solid rock, and down-cutting is proceeding actively. The solid here is the Deccan Trap.

The area has become known for two reasons. About 100 years ago a skull of *Elephas namadicus* was found near Paithan on the Godavari, in a cemented gravel. The discovery was made by FALCONER (BLANFORD, 1869, p. 70). In 1904 PILGRIM found the lower jaw of a hippopotamus and part of the skull of an elephant in the cemented gravel at Nandur which he also attributed to *Elephas namadicus*. Since this species occurs in the middle Narbada deposits it is possible that a palaeontological dating of the Godavari gravel can ultimately be carried out.

The first prehistoric artifact was found by WYNNE about 1863, again near Paithan. This flake caused great interest in those early days, as described by SANKALIA (1943, p. 6). It occurred in the river bank about 30 feet below the surface. It induced SANKALIA to undertake a fresh survey, for which he selected Niphad as his centre. He succeeded in collecting from the lower gravel about thirty cores and flakes (SANKALIA, 1943, 1945). Typologically these specimens are difficult to classify as they lack the characteristics of known industries. They were struck apparently from discoid cores and also oblong cores. This industry does not resemble that of the Sabarmati. From the purely

typological point of view it might even be classified as Neolithic, though of course the stratigraphical position disproves such interpretation. Perhaps they are no more than waste flakes, which are nearly everywhere more common than finished implements, and more characteristic artifacts may be found in the future.

The geological succession of river deposits presents the following picture.

Confluence of Vainatha Nala and Kadva.

At the village of Niphad, the Kadva, a tributary of the Godavari, is joined by a left tributary, the Vainatha Nala. The section on the left bank, at the junction, is as follows (fig. 13):

(Z) Black topsoil.

(?) 17 feet of loessic silt. This material is the most loess-like I have seen in India.

(?) 10 feet of loose gravel.

(?) 7 feet of cemented gravel.

(? Q) Brown hardened clay, resting on a rock bench about 6-7 feet above the dry-season water level of the Vainatha.

The total height of the section is 43 feet above water level. There is no fossil soil subdividing this section, which indicates no more than one cycle of increasing dryness of climate. It starts with mottled clay on an eroded surface and passes through the usual stage of coarse gravel and silt to an apparently purely aeolian silt (?loess). Whether this cycle is the later or earlier of the two we have been able to distinguish farther north, cannot be shown at this point.

The river bed at the junction presents a surprising feature. The rock surface of the bed, though very uneven, is distinctly higher in the Kadva than in its tributary the Vainatha (see p. 40).

Confluence of Kadva and Godavari.

About five miles south-east of Niphad, the Kadva joins the Godavari as a left tributary. At this point a large artificial dam is holding up the water, and the monsoonal overflow has scoured clean a large surface below the dam, where there is exposed an area of rock bench of more than half a square mile. On the left bank, a cliff about a mile long provides a section of Pleistocene deposits (fig. 14).

The section has to be considered in two parts. The upper part

(nearer the dam) rests on a rock floor which slopes downstream more steeply than does the surface of the terrace. At the dam there is 20-25 feet of deposits whilst at the down-stream end of this section there is as much as 63 feet. This rock bench belongs to the Kadva. It is separated from the channel of the Godavari by slightly higher ground. The section begins with cemented gravel resting on the rock. There is about 5 feet of it and it appears that the fossils found by PILGRIM came from this level. The gravel may be considerably older than the remainder of the section, though it need not be so. It is, perhaps, the consolidated basal portion of the overlying loose gravel which is of a finer grade. The thickness of this loose gravel varies, but may be taken to be about 2 feet. There are some gravel lenses in the higher part of the section, the remainder of which consists of fine sand and silt which is distinctly bedded in places and not of aeolian appearance. A fluviatile silty sand is found on top, and a black soil has developed on the surface. As one proceeds downstream along this cliff the rock floor continues to drop away, until a bed of cemented gravel, about 2 feet thick appears at a slightly lower level than the cemented gravel mentioned previously. This lower cemented gravel rests on clay with kunkar, much like the mottled clay of the Sabarmati. Soon after the appearance of the lower cemented gravel, the structure of the terrace section as well as the height of its surface change. The surface drops about 11-12 feet and the silts and sands are replaced by loose gravel with sand and some kunkar. The junction is almost vertical and evidently a buried cliff. It shows that a younger aggradation has been plastered against an older one: a typical case of *emboitement*.

The river has passed, therefore, through two cycles of fluviatile aggradation, separated by a period of erosion. The first cycle begins with the upper bed of cemented gravel and finishes with fluviatile silty sand. By this aggradation the river raised its bed at least 40 feet. After this period of aggradation, which must correspond to a period of increasing dryness, the river cut down. Before doing so it appears to have shifted its course somewhat to the south, on top of the aggradation. Down-cutting means increased water supply and one may, therefore, regard this as a period of a more humid climate than was obtaining previously.

It is difficult to say which deposit marks the beginning of the second period of aggradation. Approximately at the point where the lower terrace is plastered against the higher, the mottled clay appears. It is possible to interpret the situation in such a way that the mottled clay is regarded as younger than the higher terrace. In this case the overlying lower cemented gravel would be younger than the upper cemented gravel underlying the high terrace. This is perfectly possible, since cementation by calcium carbonate is a very usual phenomenon in gravel resting on an impermeable substratum. It must, therefore, not be regarded as a criterion of age. On the other hand, one gains the impression that the lower cemented gravel continues under the higher terrace (fig. 14). If this is correct the second aggradation cycle would begin with the loose gravel. It indicates another period of increasing dryness.

After this period the river cut down again and the present bed was formed. As regards the rock benches, the same situation is observed here, as at the junction of the Vainatha and the Kadva. The present Godavari, the main river, flows on a rock bench from which it descends with rapids to the valley of the tributary, the rock bench of which is lower and which contains older gravels. It appears that the main river has shifted in both cases from north to south, probably as a result of its being lifted up by aggradation. It would be interesting to know whether this phenomenon is more general in the Deccan rivers, as it might well be due to a slow earth movement.

Alternative Interpretations of the Godavari Sections.

Two successive cycles of increasing aridity are thus observed in the upper Godavari system. Whether these are the same as the two cycles of the Sabarmati remains to be established. It is possible that the very hard upper cemented gravel is the remnant of an even earlier period of river activity. Since the human artifacts recovered from this system are not sufficiently characteristic to define their age, we have to be content with stating three of the alternative interpretations possible:

(A) The lower terrace is the youngest cycle, corresponding to period (U) of the Sabarmati and the higher terrace corresponds to the

older cycle ($R + S$ of the Sabarmati). The upper cemented gravel is part of the high terrace.

(B) Exactly as (A), only the upper cemented gravel belongs to a yet earlier cycle of aggradation.

(C) The lower terrace with its underlying cemented gravel and mottled clay corresponds to the older cycle of the Sabarmati ($Q + R + S$) and the entire sequence of the higher terrace corresponds to an earlier cycle not represented in the Sabarmati sequence.

The evidence for wind action is pushed into the background by river action. This is so although a loess-like deposit was found in this area. The conspicuous deposits of wind-blown sand found 250 miles to the north are absent, and the entire sequence has a much more fluvial aspect.

VI. CONCLUSION

(1) *The Climatic Sequence and the Problem of Tropical Pluvials.*

The Sabarmati sections reveal repeated oscillations of the climate between drier and wetter conditions. The earliest evidence of wetter conditions is that of the laterite phase, which suggests a rainfall higher than the present. It is the only period which could legitimately be called a pluvial, although it too must have had a dry season. The evidence so far accumulated is not sufficient to say whether this period preceded the formation of the Palaeolithic gravels immediately, or with a long interval. The first view is slightly more probable. After the initial period, the climate oscillated around present-day conditions. It was first moderately humid and then became drier (phases Q, R and S). It became moderately humid again (phase T, red soil) and once more became drier. After these two major cycles the present land surface was formed, probably under conditions resembling those of the present day. There followed two subsequent minor periods of increased aridity, of which the last is quite insignificant.

This sequence shows that since the formation of the Palaeolithic gravels Northern Gujarat has not experienced any periods which had a rainfall heavier than at present. Since these gravels, on typological evidence, are of Upper Pleistocene or earlier age, one would have expected to find evidence of damper conditions on the grounds of the current theory of pluvials.

The theory holds that pluvials occur all over the world during the phases of glaciation in temperate latitudes. Whilst it can be shown (ZEUNER, 1945) that this theory is justified in the strict chronological sense for the Mediterranean, i.e. north of the Dry Belt, it is by no means certain whether the pluvial phases in the equatorial and monsoonal belts (collectively called the Tropical Zone) were contemporary with the northern glaciations or not. The assumption has often been made that they were, but it has never been possible to prove this.

CONCLUSION

The evidence obtained on the Sabarmati now suggests that the situation is more complex, and that the interpretation of Pleistocene deposits in terms of climate has to be worked out independently for the Tropical Zone, before a climatic correlation is attempted.

(2) *Geographical Zonation.*

The deposits of the several river systems investigated suggest a decrease in the intensity of the wind action as one proceeds from north to south. It is also evident that there were times when drier conditions than those of the present day obtained as far south as the upper Godavari. It appears, therefore, that the Dry Belt, on the fringe of which Northern Gujarat is situated, extended farther south from time to time.

(3) *Correlation of Tropical Pluvials with Glaciations.*

The relatively small distance between the area investigated and the Himalayas, which were heavily glaciated during the Pleistocene, causes one to expect evidence for corresponding pluvials. In the absence of fossils from most of the areas discussed in this paper, one might tentatively use the Palaeolithic industries to assess relative ages. The Sabarmati industry can hardly be correlated with the lower Sohan complex of PATERSON, MOVIOUS and others but rather with the late Sohan. In DE TERRA'S sequence for North-west India, based on Kashmir and Northern Punjab, the late Sohan is contemporary with the Penultimate Glaciation. If we assume, for the sake of argument, that the Sabarmati industry is of an approximately similar age, it is evident that there is on the Sabarmati no evidence of a true pluvial corresponding to the Last Glaciation. The only possible equivalent would be the red soil (T), but this for pedological reasons can hardly be taken as indicating a climate with a rainfall much heavier than the present. The whole problem of the relation of tropical pluvials to glacial phases needs fresh consideration, and India affords particularly favourable conditions for such work.

(4) *The Age of the Palaeolithic Industry of the Sabarmati.*

That the Sabarmati industry postdates the last humid period (of the formation of the laterite) does not mean that it is geologically young. It is covered by a formidable sequence of later deposits. Two ways are

open at present for dating it. The typological correlation has been pointed out in the previous paragraph. According to this and assuming that DE TERRA's dating of the Sohan is right, the industry would be of Penultimate Glaciation age or perhaps a little later. This is the most likely interpretation. On the other hand if one chooses to correlate the Sabarmati cemented gravel with the upper cemented gravel on the Godavari at Nandur, the industry would be contemporary with *Elephas namadicus*, a fossil also known from the upper gravels of the sequence of the middle Narbada (DE TERRA, 1936, p. 821). This zone, too, is correlated by DE TERRA with the Penultimate Glaciation and the tentative age obtained by the first method is thus confirmed. It has been pointed out, however, that the conditions at Nandur are not unambiguous (p. 40), nor is *Elephas namadicus* restricted to the gravels of the upper zone of the middle Narbada. More work is necessary, therefore, to substantiate the suggested age.

Assuming that the Penultimate Glaciation of the Himalayas is contemporary with that of Europe (and there is reason to believe that this is so), the age in years of the Sabarmati industry may be estimated in a very tentative way by applying either PENCK's geological dating method or the Astronomical Theory. According to either it would be of the order of 150-200,000 years.

(5) *The Age of the Microlithic Phases.*

The stratigraphical record suggests that the microlithic pre-pottery phase of Langhnaj is followed closely by the Iron Age microlithic phase. For this reason one is inclined to assign to it a comparatively recent age. In other parts of India evidence suggests that pre-pottery microlithic artifacts date back to comparatively early times, for instance near Tuticorin, as will be explained in another paper. Since the Iron Age microliths need not be older than about 2000 years, a figure somewhat higher than this will probably apply to the pre-pottery microliths of Langhnaj.

This first report on the field work done during the joint expedition of the Archaeological Department and Deccan College Research Institute will be followed by others describing and discussing the evidence from other areas visited, and the results of investigations of samples in the laboratory.

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6. Verbal Composition in Indo-Aryan by R. N. VALE. Royal 8vo, pp. xii+324. 1948. Rs. 18. [D 9].
7. Stone Age Cultures of Bellary by B. SUBBARAO. Royal 8vo, pp. viii+62. Rs. 8. [D 12].

SOURCES OF INDO-ARYAN LEXICOGRAPHY

1. Anekaraha-tilaka of Mahipa critically edited by M. M. PATKAR. Royal 8vo, pp. viii+4+215+2. Rs. 6. 1947. [L. 4].
2. Amaramandana of Kṛṣṇasuri (a defence of the well-known lexicon *Amarakosa* against the criticism of Sriharsa in his *Amarakhandana*), edited with critical introduction, notes etc., by V. RAGHAVAN. Royal 8vo, 43 pages. Rs. 3. [L 16].

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1. Words beginning with a in the Critical Edition of the Udyogaparvan of the Mahabharata by E. D. KULKARNI. Demy 4to, approximately 200 pages. [L. 10].
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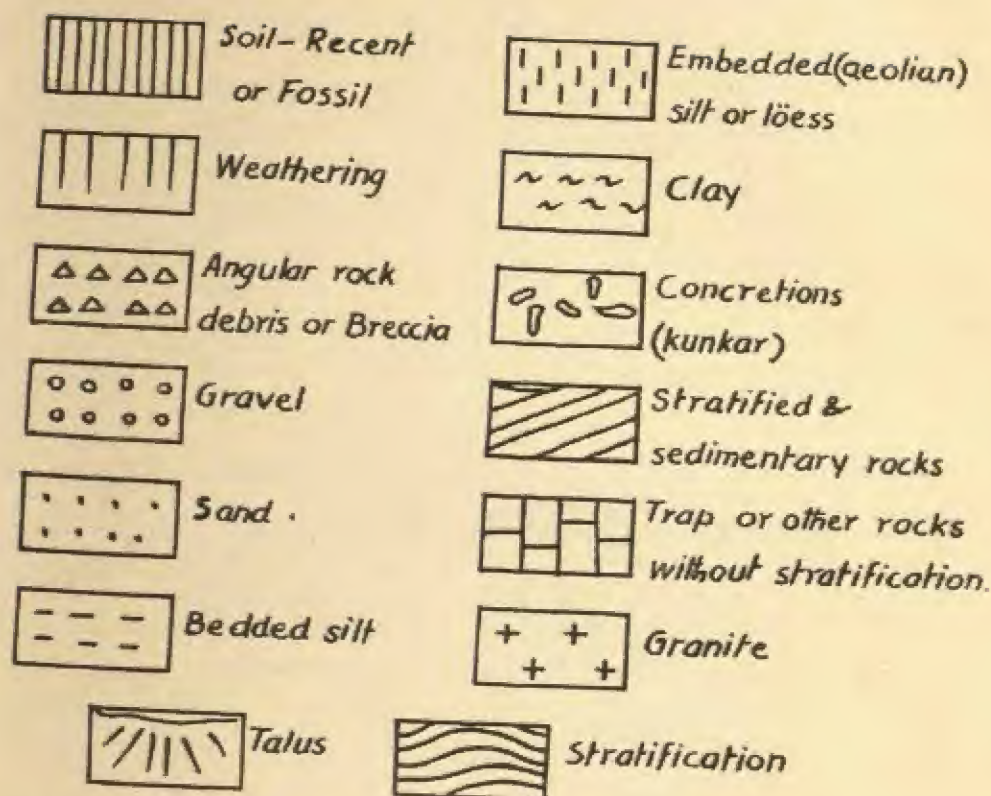


Fig. 1. Symbols used in the diagrams of the sections.

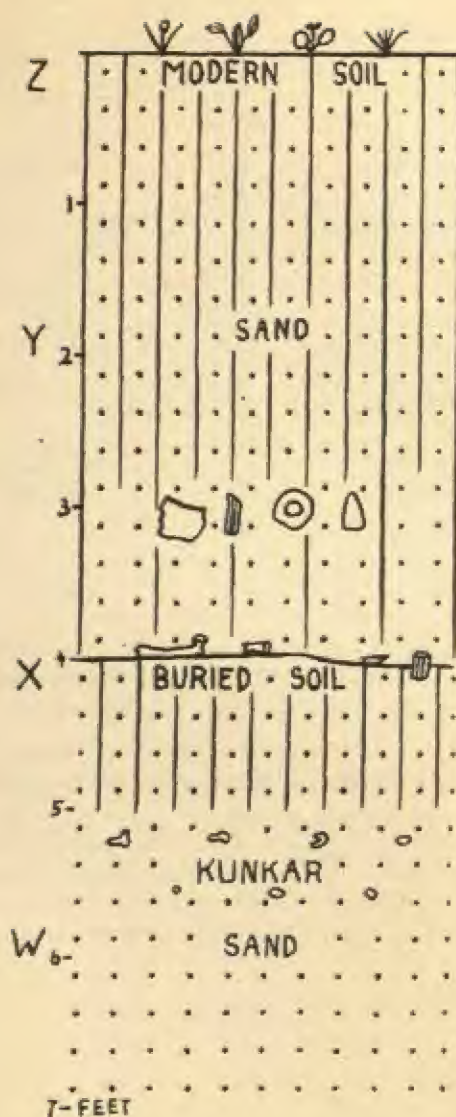


Fig. 2. Section of the excavation of January, 1949 on top of Andharo Timbo, Langhnaj, 15/1/19.

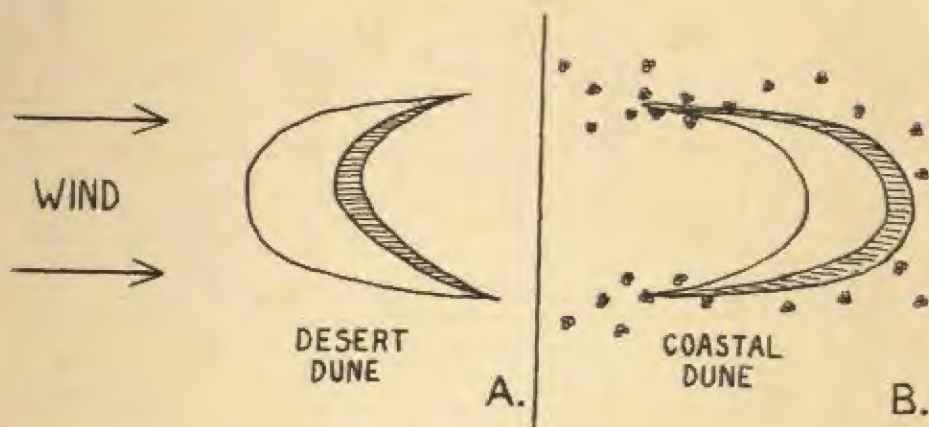


Fig. 3. The shape of dunes.

A) A Barchan or desert dune, which is not impeded by vegetation, in which the flanks of the dunes move faster than the centre. This is because the centre is higher and more sand has to be moved there than on the flanks by the same current of air.

B) A dune of the "coastal type", which, however, is not confined to the coastal areas, but found wherever moving sand competes with vegetation. Plants try to grow on the sand, attacking the dune from the side. The sand is therefore fixed by the vegetation on the flanks while the main body of the dune is still capable of moving. The result is that the flanks of this type of dune are drawn out against the wind. These dunes cannot move very long because sand is continually being caught by the vegetation. Note that the steep side of the coastal dune is on the convex side, whilst on the desert dune it is on the concave side.

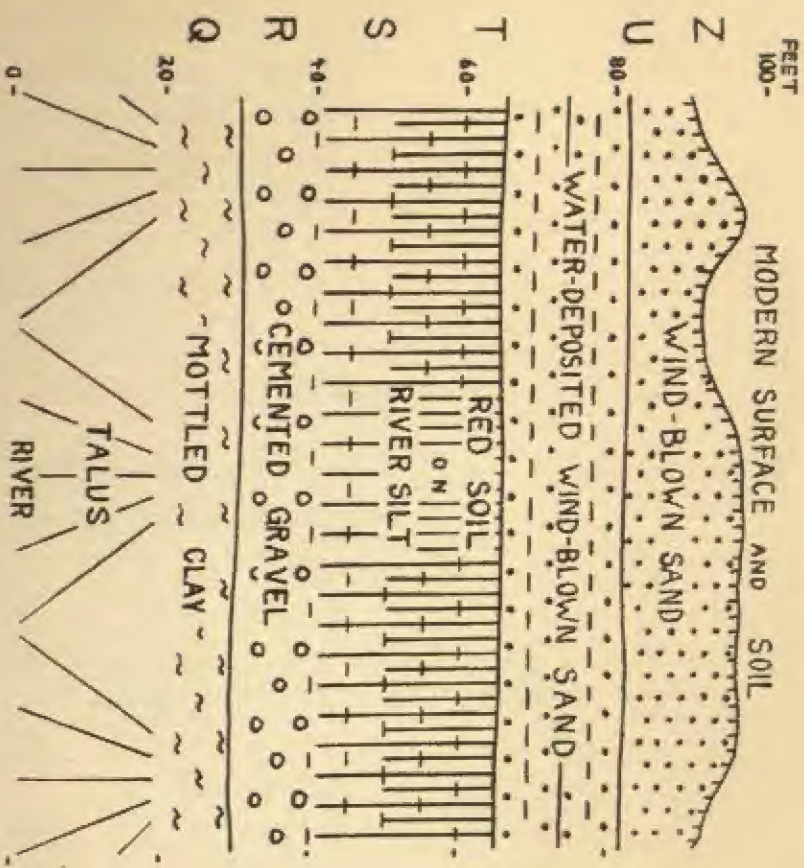


Fig. 4. Sabarnati cliff at Hirpur, 16 & 28/1/49.

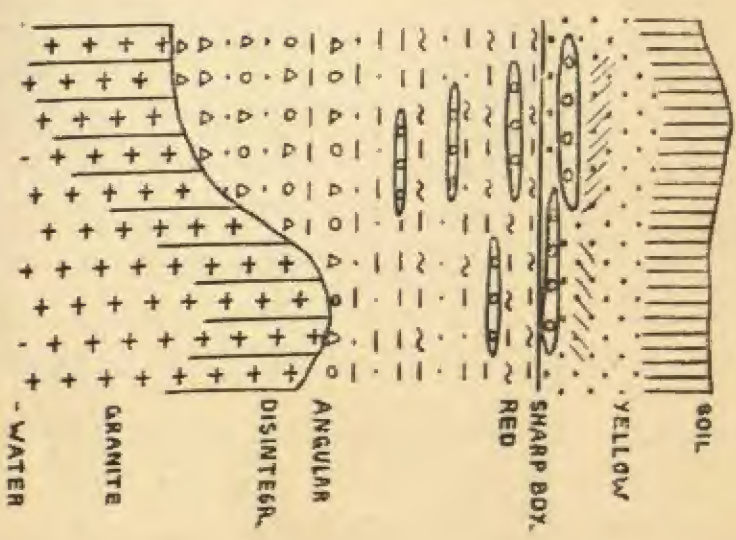


Fig. 5. Sabarnati cliff at Juna Hadol, 23/1/49.

Fig. 6. Section of the most northerly of the two knoelin pits on the right bank of the Saharnati, near Kot, 20/1/49.

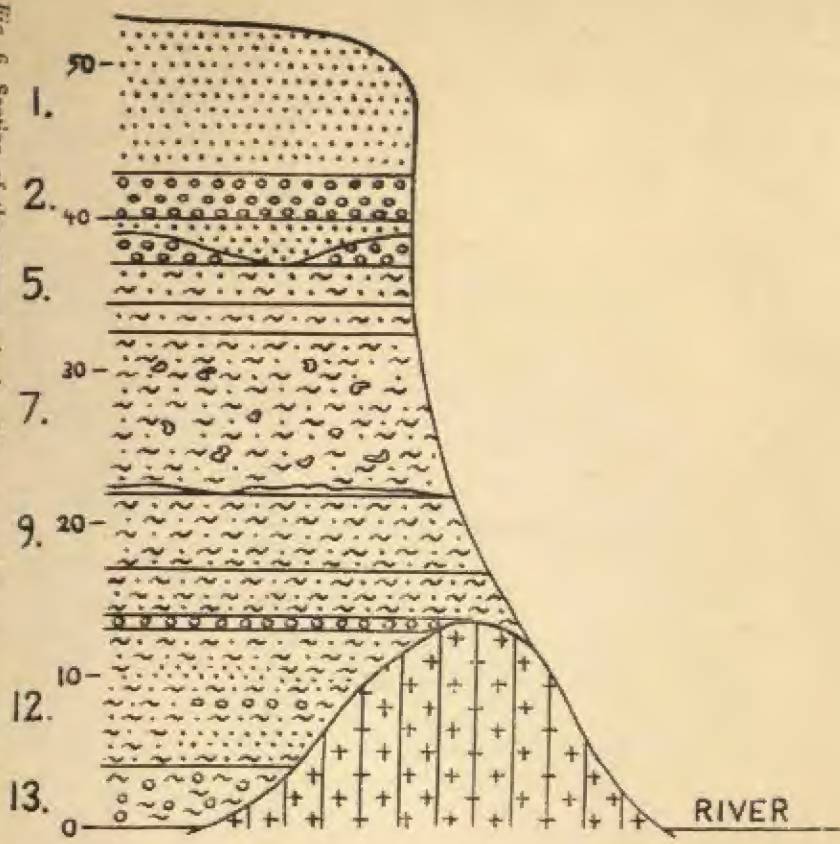
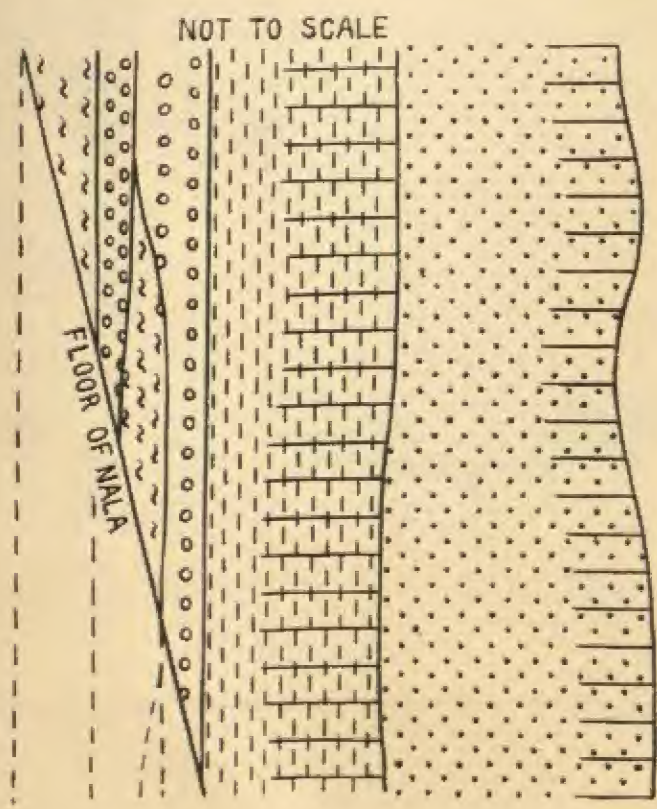


Fig. 7. Section of the lower part of Ghoghudwani Oghu, 17/1/49.



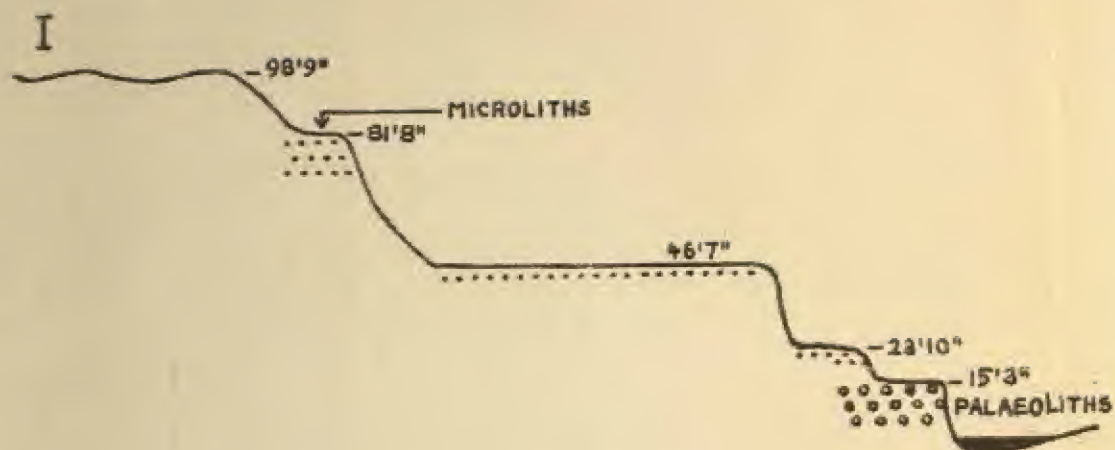


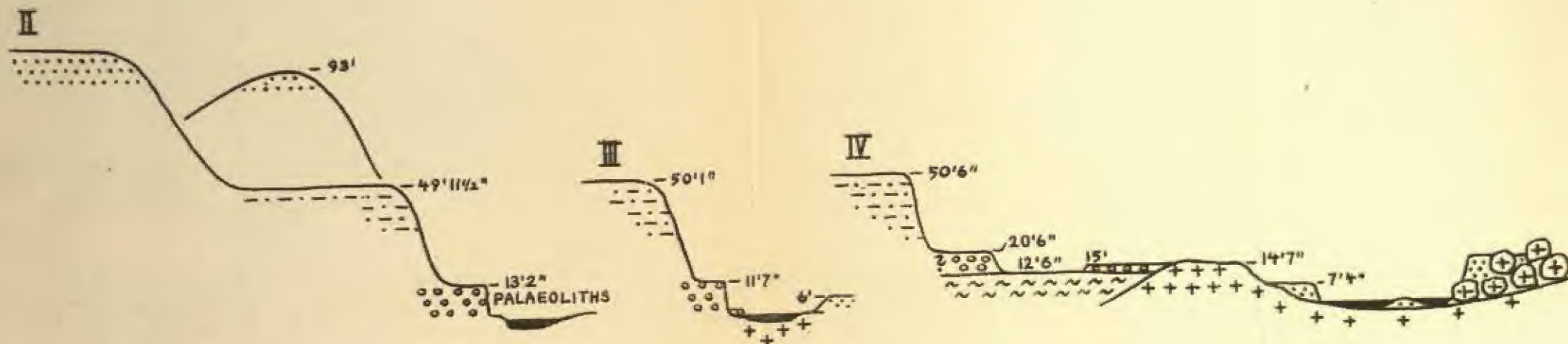
Fig. 8. Cross section of the right bank of the Sabarmati river downstream from Valasna.

I) Near the Thakorsaheb's bungalow at Valasna, 28/1/49.

II) Half a mile downstream from Valasna, 24/1/49.

III) About one mile downstream from Valasna, 24/1/49.

IV) About one and a half miles downstream from Valasna, near Sundarpur, at the microcline barrier, 24/1/49.



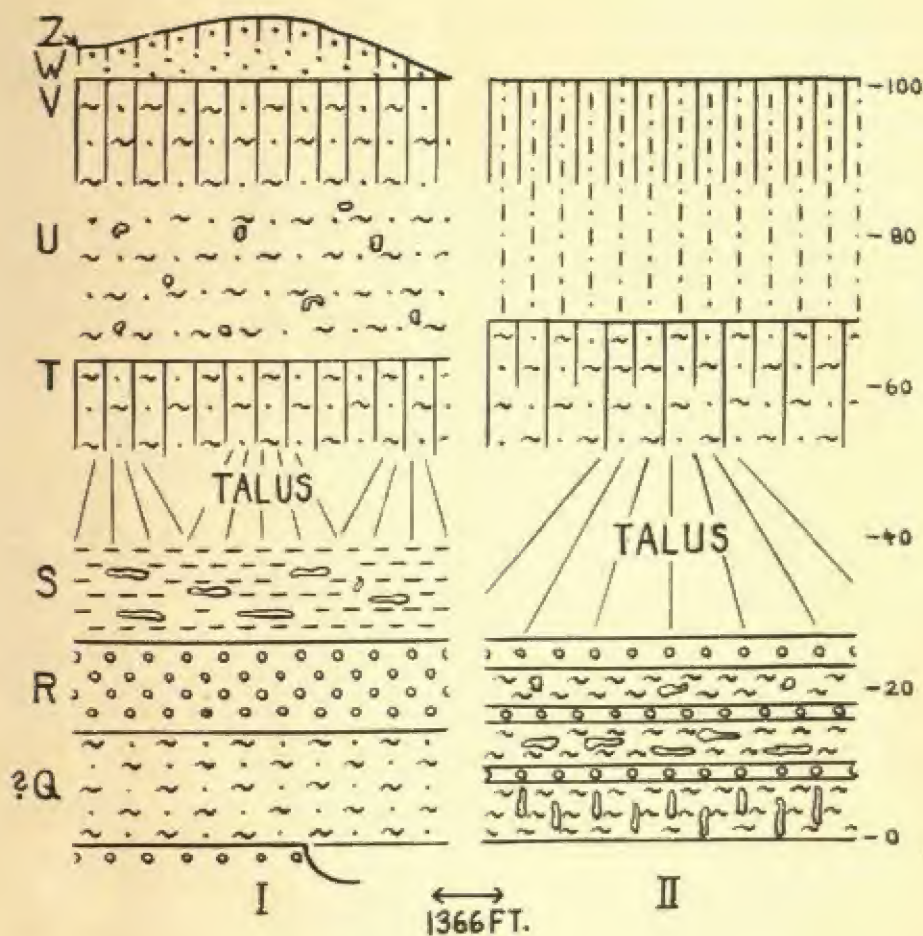


Fig. 9. Sections on the left bank of the Mahi river, 3/2/49.

I) Near Raika village.

II) Downstream from I.

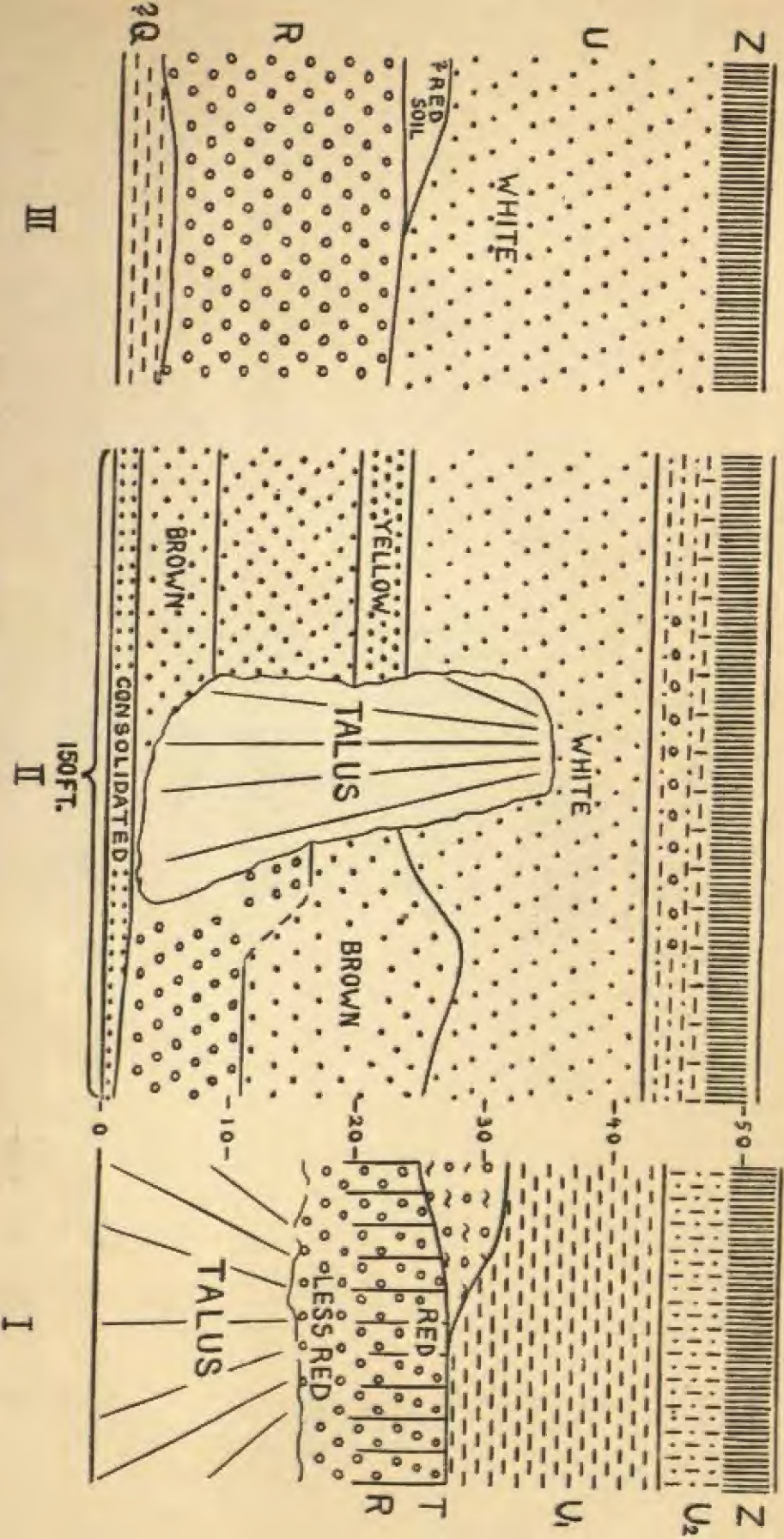


Fig. 10. Sections on the right bank of the Orsang near Kundya Nala, Bahadarpur, 7/2/49. (I) One furlong upstream from the nala. (II) One furlong downstream from the nala. (III) 200 yards downstream from II.

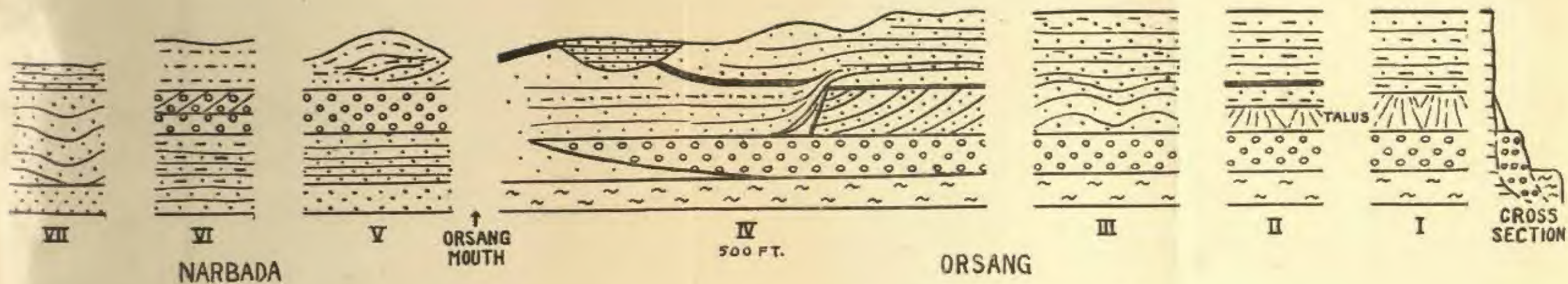


Fig. 11. Seven sections from the right bank of the Orsang and the Narbada, upstream from Chandod, 8/2/49.

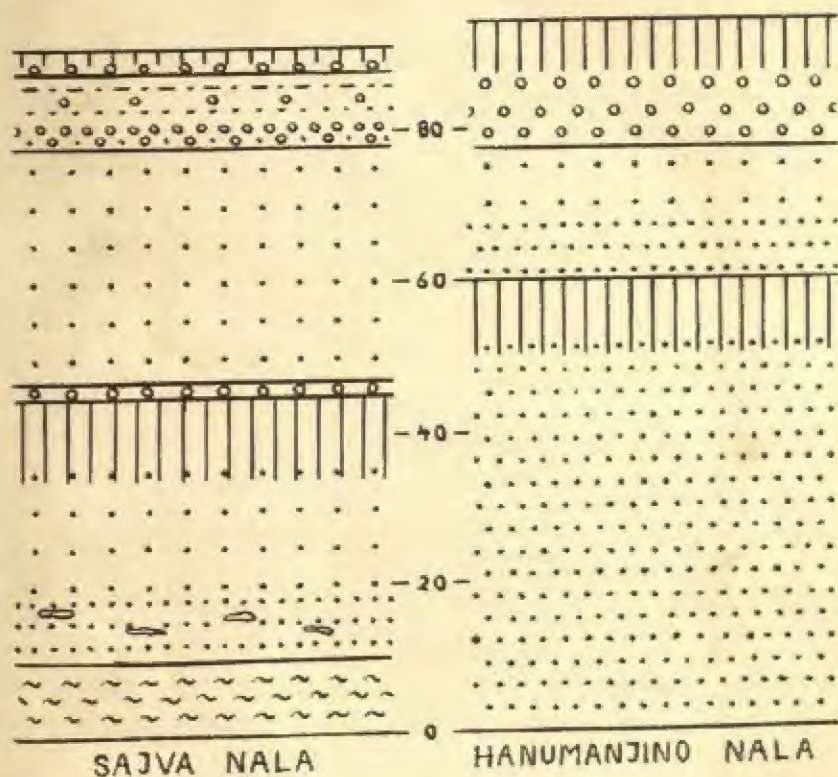


Fig. 12. Sections of the left bank of the Karjan river at Sajva, west of Rajpipla, 9/2/49.



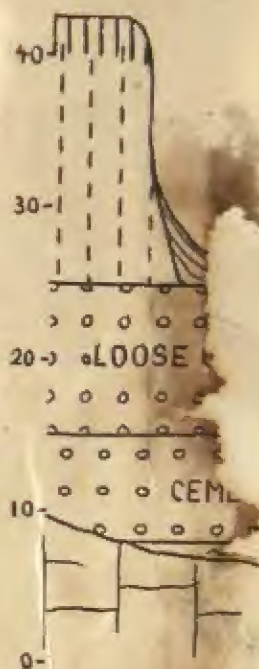


Fig. 13. Sec

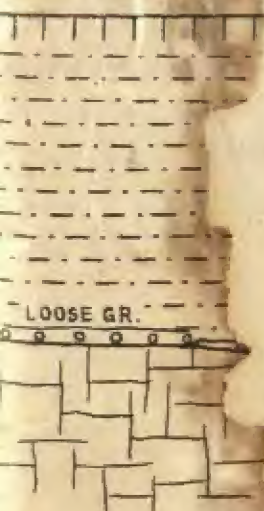
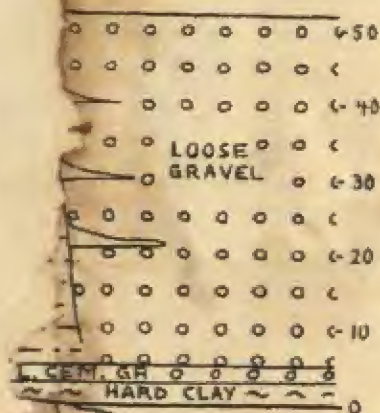


Fig. 14. Section on the left bank of the Godavari at Nandam 17/2/49.

VAINATHA

adva, 16/2/49.

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